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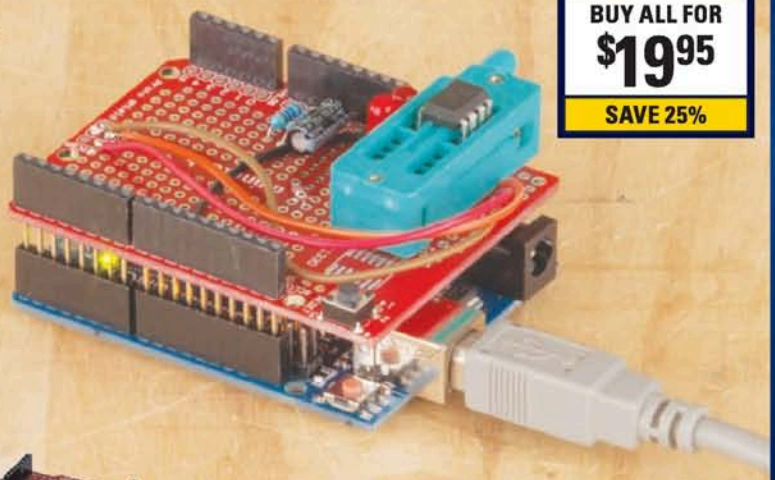

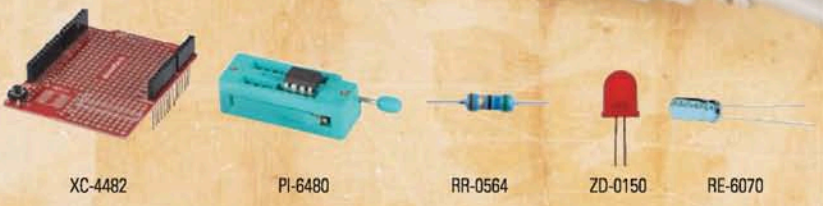

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Publisher's Letter

Thirty years – and still going strong

Looking back on 50 years in publishing is a daunting exercise. I started work at *Electronics Australia* in May 1967 and after two stints there, ended as managing editor.

Greg Swain and I started Silicon Chip Publications in July 1987. Our first issue appeared in November 1987. John Clarke and Bob Flynn came with us from EA and while Bob and Greg have since retired (in August 1999 and November 2016 respectively), John Clarke is still with us (albeit now "telecommuting" from northern NSW), along with other very long-serving staff such as Ann Morris and Ross Tester.

In fact, one of the stand-out factors in the success of SILICON CHIP has been the loyalty of our staff, our regular contributors, our readers and our advertisers. Two of our most staunch advertisers, Altronics and Jaycar Electronics, supported us right at the beginning and are still our strongest supporters today. We sincerely thank them. Our subscribers and readers have also been very loyal – we still have our very first subscriber, Deogracias Haw, who lives in Taiwan.

And while we have been successful, that is not to say the path has been smooth and easy. In fact, for much of the time it has been quite arduous. At the time we started, there were three other monthly electronics magazines: *Electronics Australia, Electronics Today International (ETI)* and *Australian Electronics Monthly*, plus a number of trade magazines which were very strong for a while. We have seen them all off, as well as virtually all of the equivalent electronics magazines around the world. Very few survive.

Then we ran up against very difficult trading conditions in the quite severe recession of the early 1990s when interest rates rose as high as 18 per cent (thank goodness we had very little debt!). We managed by running a very lean operation and we continue to do that right up to the present.

After the 1990s and the "recession we had to have", we had pretty good economic conditions until the global financial crisis and it really started to bite in around 2008. Arguably, Australia and the rest of the world are still feeling the effects and will continue to do so for many years. Over those years, many of our advertisers' businesses failed, most large-scale electronics manufacture in Australia has long ceased and many skilled engineers and technicians have either retired or lost their jobs.

Around ten years ago the internet really started to gain momentum and its rise has made magazine publishing extremely difficult, as magazines and newspapers have struggled to adapt or die. A great many magazines in all categories have ceased publication. At the same time, the internet presents us with an opportunity as we too attempt to adapt to it.

But I am confident that SILICON CHIP will continue its success into the future, particularly with Nicholas Vinen as the Editor, as well as our loyal staff and supporters. Nicholas has a wonderful grasp of the whole electronics scene and can see the opportunities of the magazine in the future. I am also confident that printed magazines will continue for many years into the future but there is no doubt that digital publishing will continue to grow.

One aspect will not change. SILICON CHIP will continue to have a strong DIY electronics emphasis, as well as attempting to cover as wide a range of related subjects as possible. We will also continue to comment on the wider issues facing Australians as technology accelerates ahead and controls every aspect of our lives, be it economic, environmental, health and communication.

Thirty years ago we could not imagine the huge changes in every facet of our lives. And try as we might to extrapolate, we cannot begin to imagine the changes which will come in the future. Many of the changes of the past thirty or more years have been quite positive for humanity, but will the changes of the future be similarly beneficial?

Let us not merely hope for the best but strive for the best.

Leo Simpson

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Standard PCB component libraries not always available

I noticed in a recent editorial that you mentioned that you use Altium software for your designs. I can't afford the full Altium product, but I recently bought their Circuit Studio software.

It is a bit of a curate's egg. I've beaten most problems into submission, but the component libraries are a real chore.

Weirdly, even though some libraries are huge, I've had a struggle finding definitions for simple through-hole components like 74HC00, 74HC74 etc.

Although the Altium support people told me where to find suitable definitions, they are well hidden, and it is a big chore to make them available to Circuit Studio.

Even more weirdly, definitions of really simple components like resistors and capacitors are so elusive that I've resorted to making my own.

So far, with quite a lot of effort, I've defined just three capacitors, two resistors, and one transistor. Just the symbol and footprint, no SPICE models or anything clever.

I think that Circuit Studio shares most of its library technology with the full-strength Altium product and it occurred to me that most of your designs use components from Jaycar and/or Altronics, so either you've found where these are defined in libraries available to Altium, or you've defined them in your own custom library.

Is this an opportunity for a win-win for you, Jaycar and Altronics and wannabe designers like me?

Oh. I also wonder if any other readers have bought Circuit Studio.

Keith Anderson,
Kingston TAS.

Response: we have commented about this in the past and it isn't just limited to Altium Designer/Circuit Studio. EAGLE is arguably a bit better but the libraries supplied with it are far from complete and require many modifications to be usable.

Keep in mind that many of Altium's paying customers will be doing SMD-heavy designs so they are going to provide many more libraries with SMD components than through-hole (representing the current state of commercial electronic design).

We have been using our own libraries for over a decade now. We do frequently copy components from manufacturers' libraries into our own (often with modifications) but we have made most of them ourselves, including 3D models.

Once you have a bit of practice it isn't too hard, especially since for most ICs you just need to copy another and change pin assignments, but it's still a huge amount of work overall and even a small error can ruin a design.

Etone woofers are still available

I am currently building the Majestic loudspeakers, described in the July and September 2014 issues (siliconchip.com.au/Series/275).

I have seen a couple of letters recently which state that the Etone driver

A personal connection to WRESAT and reasons for optimism

I enjoyed reading your lead article by Dr David Maddison in the October edition of SILICON CHIP regarding Australia's first satellite, WRESAT.

The 50th anniversary of WRESAT's successful launch from Woomera in South Australia occurs on the 29th of November this year. With WRESAT, Australia became the third or the fourth country in the world to launch a satellite from its own shores (depending on one's definition of "own shores").

The anniversary provides us with an opportunity to reflect on this major milestone in Australia's scientific history.

I have a strong personal interest in WRESAT as my father, Professor John H. Carver, led the University of Adelaide team which, with a team from the Weapons Research Establishment (now Defence Science and Technology Group) designed and built the satellite which was mounted on a Redstone rocket donated by the USA.

Unfortunately, there was little follow up to WRESAT, for example to develop a space industry in this country. My father stated such with the following comment from an interview he did for the book Space Australia by Kerrie Dougherty and Matthew James, published in 1993:

"At that time there was a great capability in rocket production available in this country, but unfortunately that has since disappeared, many of those skills being lost as the work stopped in the 1970s..."

"My great regret over WRESAT was that there was never a WRESAT-2. The Americans offered us a significant number of Redstones at a very modest price, but the Australian Government decided that there was no interest in developing a space program.

Consequently, although at that stage we were the fourth country to launch a satellite from its own territory, we didn't take up the opportunity."

However, there have been some positive developments of late in redressing this inaction with the very recent announcement that Australia will establish a Space Agency, a move that will enhance our presence and potential in the burgeoning space industry, and in space science.

John A. Carver,
Acton, ACT.

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for the Majestic project are no longer available.

Nothing could be further from the truth. Etone is run from a corner of a factory in Bankstown by a man named Wales. I ordered a pair but rather than getting them delivered by parcel post, I went and picked them up. Also, the crossover components including the 2.7mH inductor are available from WES components.

I have no connection with either company except as a happy customer.

Terry Bilson,
Asquith, NSW.

Comment: this is good to hear since the Etone woofers are much cheaper than the Celestions and we think they sound better, too.

Valve radio power supply is safe

Referring to your article in the August issue of SILICON CHIP on the Mains Power Supply for Battery Valve Radios (siliconchip.com.au/Article/10751), take a close look at your wiring diagram that feeds 230VAC to transformer T2. The diagram shows the thermal fuse in the neutral lead.

If this is the case, when the thermal fuse goes open circuit, it leaves the transformer live to 230VAC – not a desirable outcome if the primary winding happens to leak to the core. It becomes a potential shock hazard.

Dennis Seymour,
Auckland, New Zealand.

Response: the figure-8 mains input connector is not polarised so the Active and Neutral indications for CON3 are just an example. Changing the wiring of T2 would not make any difference. A transformer with a primary winding leak to the core will always be a shock hazard, regardless of the way it is wired and part of the design of a modern mains transformer is to provide sufficient insulation to make this very unlikely.

Error in WRESAT article

No doubt other readers of the fascinating article on WRESAT, SILICON CHIP October 2017, would have noticed the error on page 20. The first American in space was indeed launched atop a modified Redstone missile launch vehicle on 5th May 1961 in a Mercury capsule, Freedom 7, but the second person in space was Alan Shepard, not John Glenn as stated in the article.

It was a suborbital flight. Russian Yuri Gagarin was the first person in space, completing an earth orbit in Vostock 1 on 12th April 1961. John Glenn was the first American to orbit the earth, the third American and fifth person in space on 20th February 1962 in Mercury capsule, Friendship 7, atop an Atlas LV-3B launch vehicle.

Grant Carr,
Adelaide, SA.

Note: this error was introduced in editing. Thanks for letting us know.

Gas shortages are artificial in nature

I found your editorial in the September 2017 issue to be interesting reading ("A rapid shift to electric vehicles could be disastrous"). First of all, I do not believe there is a shortage of gas here in Australia!

Any shortage is due to the fact that the corporates chose to flog it off for maximum benefit while we here in Australia, the so-called Lucky Country, get what is left over. Governments have not been diligent in making sure this cannot happen and indeed have allowed it to happen. There should be a guaranteed quantity quarantined for use in Australia, for both domestic and industrial use at reasonable cost.

First and foremost, this is Australia, it is our gas and we should benefit from this, our resource.

With all of these batteries that we will soon rely on, what is the impact environmentally, during manufacture, and at the other end of the life cycle; what happens after they reach the use by date? Just take a look the problem created by used tyres.

Bob Quinn,
Launceston, Tasmania.

Comments: we generally agree with you but a shortage due to contractual obligations is still a shortage. The new Australian Domestic Gas Supply Mechanism, which came into effect on July 1st, should prevent actual shortages but prices are still quite high.

On September 25th, Prime Minister Malcolm Turnbull made the comment that if NSW and Victoria approved more Natural Gas exploration and extraction projects to proceed, there would not be a shortage and we think he's probably right.

The environmental impact of battery manufacture and recycling depends on a number of factors such as the exact chemistry used, the mines used to produce the raw materials, the processes used to produce and recycle the batteries, etc. There is no simple answer. We suggest you do some research on Google. A quick search led us to this report: www.battery-recycling.org.au/environmental-impact-of-lithium-ion-batteries

Cape York better for launching satellites than Woomera

Thank you for the October issue. Once again, it is good reading. Also, congratulations on achieving 30 years of publication. I hope I live long enough

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to see both the 40 and 50 year editions.

I agree with most of the comments in the October Editorial Viewpoint. But Woomera is not a good site for launching satellites. It is a good missile testing site but the best location for satellite launching is Cape York in Queensland.

It is no accident that both the Americans and the French have their launch facilities close to the equator. That extra kick from the earth's rotation makes the launch cheaper.

We would be better to build launch facilities at Cape York for hire than to do everything ourselves and I would not be surprised if both the Americans and French used the facility as a back-up and to increase their capabilities.

George Ramsay,
Holland Park, Qld.

What will happen to vintage radios if AM broadcasting ends?

I was very interested with the articles about DRM (Digital Radio Modiale) in the September 2017 edition of SILICON CHIP (siliconchip.com.au/Article/10797). Especially where it points out that we here in Australia are lagging behind the rest of the world (yet again) with the our usage of the electromagnetic spectrum.

I wondered whether SILICON CHIP is to blame for this when I arrived at page 100 of the same edition and saw the Vintage Radio column! (I'm joking, of course.)

Will it be worth restoring these fine old monsters once they no longer have anything to receive? Will they only be useful as decorations? If so, only the outer cabinet needs restoring; the electronics inside can be consigned to the bin. (Wink, wink.)

Bob Graffham,
Sanctuary Point, NSW.

Comment: Even if AM radio broadcasting stops , it won't for a long time. Even then, vintage enthusiasts will still be able to operate their restored radios by building their own low-power transmitter. In fact, we published a suitable design in the January 2006 issue (siliconchip.com.au/Article/2534). All the parts can still be purchased and the PCB is available from our on-line shop.

Crimp ferrules solve wire strand fracture problem

Reading Mailbag, May 2017, I am baffled by Ranald Grant's terminal selection conundrum to avoid wire de-stranding and fractures. Surely the best practice would be to use a bootlace-ferrule hand crimping tool. These are dirt cheap and readily available from numerous Asian suppliers.

I own two of these tools. One is a 4-jaw (square-section crimp) for flat-bottom terminal port-entries and the other, a 6-jaw (hexagonal-section crimp) for rounded or tunnel-port terminal entries. Problem solved – no special terminal blocks required!

I would also like to ask whether any reader has a pneumatic fluidic-logic tutorial kit sold by Plessey in the 1960/70s. I would like to know more about it. If so, please drop me a note at pyralog@yahoo.co.nz

Andre Rousseau,
Auckland South, New Zealand.

No major obstacles for transition to electric vehicles

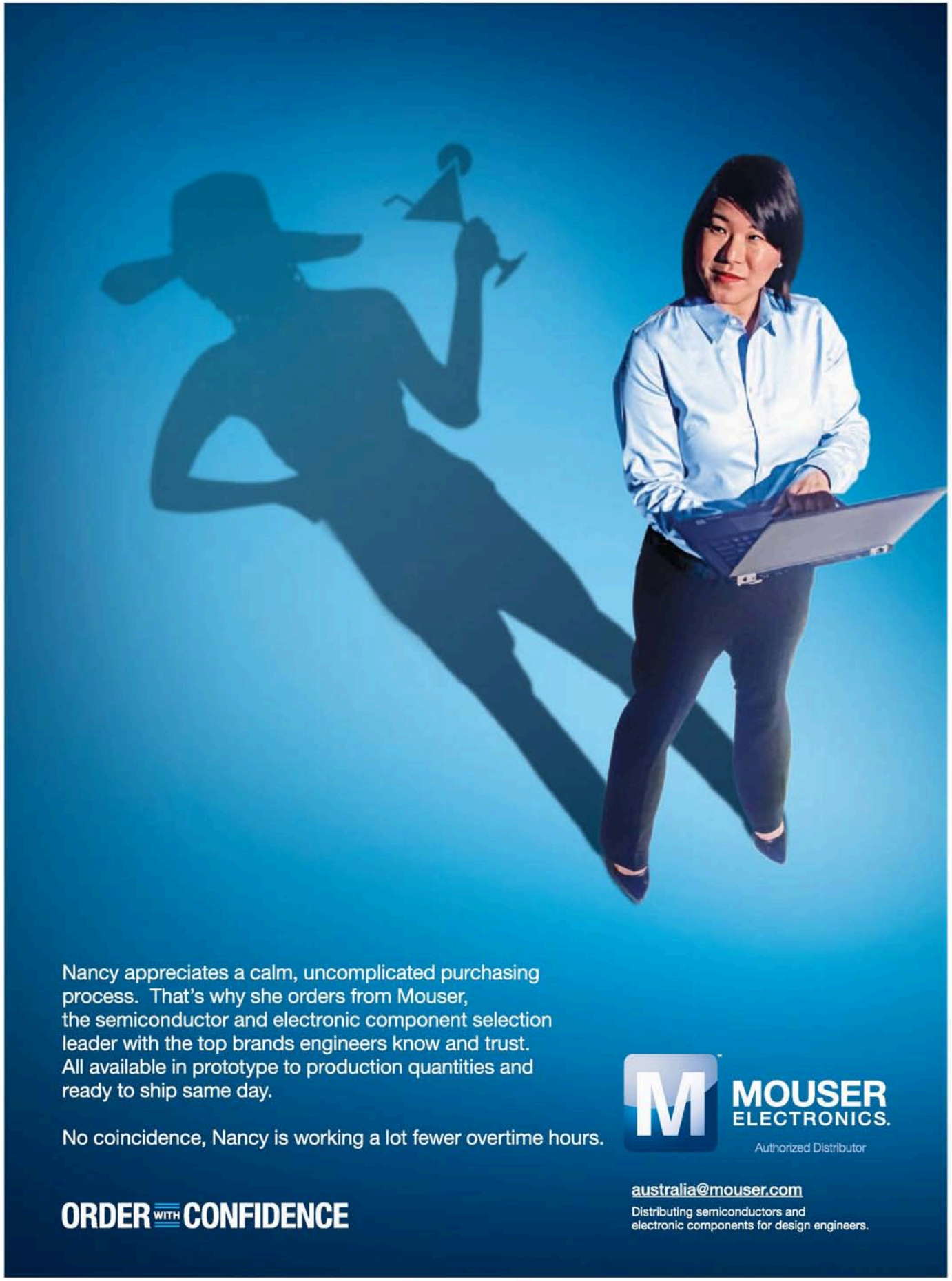
I read with interest your Editorial (September 2017), and thought, Nostradamus you ain't! You do not appear to be a student of history. Being much older than you, I have lived through disasters such as you predict (electricity, fuel strikes, natural disasters etc), and, whilst inconvenient at the time, the world just keeps rolling along.

I have also seen an efficient private enterprise cartel (including AEMO) take the old SEC system from providing the cheapest electricity in the world to the dearest by ripping off the customers, whilst retaining the same system, and this in view of flat or falling electricity consumption since 2007.

The scenario you propose will not affect me at all. In 23 years time (2040), if I am still alive, I will probably have an electric car, as this is likely to be the vehicle of choice.

However, as I have a solar system, to which I have adding batteries, I am independent of the grid. To cope with the additional power usage for a car, I will simply add more panels. As there are 1,700,000 solar panel installations in Australia, I predict many of them will do likewise.

On the subject of battery production, people like Elon Musk (Tesla) and his competitors will take care of supply. The large battery supplied in only 3 months in South Australia is an example. My prophesy is that shares in lithium or battery enterprises will do well in the next few years.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I am surprised that you, as a supposed technical literate person believes the propaganda put out about the need for backup. The fallacy of this is shown in England, where a nuclear power station has reached the end of its working life (Battersea?) and is being replaced by a giant wind farm (Jodrell Bank?), without any backup.

I lived for years off grid without needing backup, so know that the wind does not generate 30% of the time, as dictated by our economic system but rather 90 to 100% of the time. Solar systems should have batteries as an integral part of the system for time shifting, rather than an optional extra.

I suggest you put aside the Aussie characteristic of knocking and look at the future in a positive and constructive way. I am.

David Tuck,
Yallourn North.

DCC booster requires quality optocouplers

I am writing to you regarding the 10A DCC Booster project published in the July 2012 issue (siliconchip.com.au/Article/614) which was sold as a kit by Oatley Electronics. This booster is bullet (and short-circuit) proof, but, as Jeff Monegal has said to me, has one Achilles heel. The 6N138 optocoupler.

This is not Jeff's fault; the varying and sometimes pathetic production quality from some manufacturers means most of them don't work as this project requires (and as spec sheets say they should).

The only reliable unit I have found is Toshiba's 6N138 in white packaging, which I acquired from element14. To allow for variable quality, I bought 10 of them, and I was pleasantly surprised when all 10 worked perfectly. This is the only swapout that was required in the end.

I hopes this helps others having issues with this great kit.

Peter Bassett,
Barellan, NSW.

Comment: Thanks for this information. We hope to upgrade this project sometime next year so we will keep this in mind.

Take care earthing Currawong mains transformer

I have been looking at the mains wiring diagram for the Currawong stereo valve amplifier on page 91 of the December 2014 issue (siliconchip.com.au/Article/8122). Having been around the block (with grey hair to prove it), I noticed that when connecting an earth wire to a toriodal transforrmer, constructors use the supporting screw as a convenient location to secure the mains earth wire to the chassis.

This is not good as this will form a shorted turn between equipment and cause primary fuses to blow. I hope this makes sense to you. Otherwise it's a great, detailed project that I enjoyed reading.

Barry Sandeman,
Cape Town, South Africa.

Response: we published a panel regarding this issue on page 65 of the January 2015 issue, in the third instalment.

It's titled "Transformer Bolt Earthing — Warning!" and points out that the mounting bolts for the transformers must not be earthed if they are installed in a metal (conductive) case, for the reason you stated.

However, in a timber case, the mounting bolt should definitely be earthed, especially if it protrudes from the bottom of the case or else

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it becomes a shock hazard should a wire come loose and contact it.

Much more advanced data logger wanted

I have bought the parts to build your Arduino Data Logger, from the August & September 2017 issues (siliconchip.com.au/Series/316) and am in the middle of assembling it.

I like the design for what it is, ie, an easy-to-use logger for limited tasks.

I am setting up a solar PV system. I would love to monitor the voltage on each of my panels, as well as other parameters. What I would like is some kind of logger that would:

1. Allow for positive and negative voltages.
2. Make it easy to adjust the input voltage ranges.
3. Handle (say) up to 64 inputs.

I have no need for any great speed of reading the voltages.

Many years ago, *Australian Electronics Monthly* published a design for a Serial Data Logger, two of which I built and used. The project was based on an ADC chip that had an eight-way multiplexer. One sent a byte of 0-7, the chip converted the voltage on the corresponding input and sent the eight bit value back in one byte.

Of greater relevance to the current project is that the AEM design had op amp buffers for each input. These op amps could shift voltage levels (to handle negative voltages) and the gain of the op amp was set by selecting resistors. One could configure each input as either amplifier or attenuator.

I *may* be able to find the original article, but, it would take me a long time. You probably have access to resources that I do not have. Might I suggest that you consider a new version of your current Arduino Data Logger project.

It might have:

1. Eight inputs with the op amp buffers with level shifting and adjustable gain or attenuation. Optional input series capacitor for measuring alternating current. Optional parallel capacitor for smoothing noisy inputs. It would only need one connectionto the Arduino ADC port.
2. Screw terminals for ease of installation in the field.
3. Ground screw connections next to each input connection, to simplify wiring.
4. Some method of selecting which Arduino ADC your board connects to. This would provide a multiplexing function in software.
5. The ability to stack multiple Data Logger boards for more inputs.
6. Some method of setting the board address. This might involve stealing the digital inputs to provide address selection to the boards or it might involve some kind of buffer or analog switch that enables the voltage inputs with only the board which is currently selected. With four Arduino ADC ports and four bit addressing of your new boards, one could have up to 64 inputs, just what I want.
7. In the August issue of SILICON CHIP, there was a suggestion that you might do a Micromite version. I have been using Micromites with the ILI9341 screen and I find that environment fairly comfortable. You might consider using the new Arduino Data Logger as an ADC Engine and using a Micromite as a controller and display.

By the way, why did you not base your Data Logger on an Arduino Mega? If you could squeeze 16 inputs with screw connections and the op amp buffers onto a shield to fit a Mega, one could then have two hundred and fifty six inputs – enough for many people.

I am having great difficulty seeing well enough to solder the modern surface mount parts. I would be happy to pay you for kit boards with the surface mount chips already installed.

This applies also to the later 64 and 100-pin Micromites with the surface mount chips, which I would love to use.

Likewise, it would make me very happy if SILICON CHIP could sell me some bigger LCDs that would fit the Micromites. My eyes would like the seven or eight inch touch screens. I do not want to use eBay.

I am much happier writing software than designing hardware. I hope that you can do that for me.

Patrick Berry,
Turramurra, NSW.

Response: what you are asking for is quite specialised and we doubt that many readers would need such a complicated data logger. Have you seen Bera Somnath's CANBUS-based solar monitoring system design which we published in Circuit Notebook, May 2017 (siliconchip.com.au/Article/10656)?

His system monitors the current from each panel, rather than voltage; this is easier since isolated current monitor modules are cheap and readily available. It uses a separate Arduino board for each panel or set of panels, making the bus wiring easier. This may be more feasible than what you are suggesting.

Given the high voltages common in solar arrays, for accurate logging, you would need a high-voltage multiplexer (likely made from dozens of discrete components) and a difference amplifier feeding an ADC. That would make for a significantly larger and more complex project than the Data Logger that we just published.

Cautious but optimistic about electric vehicles

I agree we should be cautious about rushing into the electrification of transport.

Like you, I do wonder how far it is practical to go without destabilising provision of services. This particularly applies to emergency vehicles used in natural disasters. Recent weather events in NSW and Florida should caution us about putting all our eggs in one basket.

However, as an electric vehicle (EV) owner, I am pleased to see governments finally taking EVs seriously. Banning ICE (internal combustion engine) powered vehicles will galvanise car makers, and about time.

Most of them have been asleep at the wheel. Time is wasting and the need to limit global warming is real.

The rate of EV market penetration is currently limited by battery production. For the next four years, that means you will be mainly dealing with Nissan, Tesla and soon, the Chinese. Our EV market is embryonic at best, mainly due to a total lack of government interest. The USA, Europe, China and Japan are seeing a steep rise in EV demand, on the other hand.

Norway's high uptake status is anomalous, being driven by generous government incentives.

Tony Seba from Stanford University gained credibility by predicting the dominance of smartphones. He forecasts that an EV price point inflection will occur by about 2021. EVs will then become cheaper than petrol cars. Guess what happens then?

Elon Musk, of Tesla Motors, estimates that full transport electrification would roughly double the

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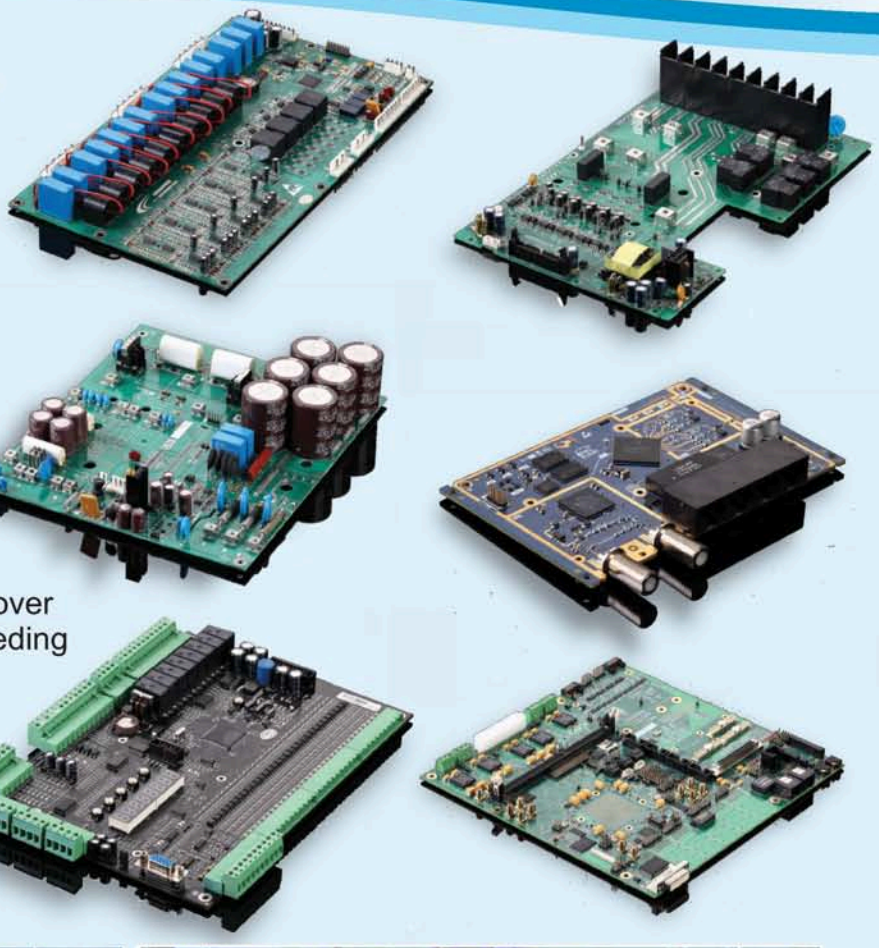

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electricity budget of a country like Australia. On the face of it, we are unprepared for that sort of demand.

However, it's not all bad. In the short term, lack of availability/affordability will buy us some time. Home charging using off-peak power (or domestic solar and Powerwall battery) can take care of commuter needs with existing power networks.

A large fully electric car can comfortably charge overnight, using a 240VAC 32A circuit. This is about the same power allocated to a domestic stove.

Also, Musk has committed Tesla to power all public supercharger stations with roof-mounted solar panels, thus helping distance travel. He claims that supercharger stations will eventually be net contributors to the grid.

This is already impacting on the USA's energy balance. In June 2013, just one year after Tesla's release of the Model S sedan, their (then) fledgeling supercharger network was only partly solarised.

Despite that, it collected solar electricity equal to 25% of the Hoover Dam output for that period! The number of Tesla superchargers has gone up about tenfold since then.

Solar powering the network is understandably trailing this development but is steadily proceeding. The new Tesla solar roof panels resemble grey slate but are actually all solar cells!

Elon Musk claims to be making a "compelling case" for going solar on domestic roofs. An understatement, I think. Compared with tiles, Tesla's roof materials not only generate power but are stronger and cheaper.

If you have not been following Musk's various businesses, then you risk being under-informed, because everyone else seems to be floundering in his wake. No doubt you have magazine space earmarked to cover the new 100MWh South Australian grid storage battery.

The future for alternative liquid fuels is also brighter. It is worth mentioning some recent Japanese research, reported on NHK. Researchers made synthetic crude oil by growing certain algae in a setup similar to a sewerage treatment plant.

No sewage was involved; only water, algae and sunlight in a mechanically stirred open pond. The input materials were sunlight, air and water. The output material was filtered and purified algae.

It looked and smelled like crude oil and could be processed into fuel by existing oil refineries! Even better, it is burned back into carbon dioxide and water.

I am sure in the future, common sense will prevail and the reality will be a hybrid energy mix somewhere in the middle. Water will find its own level, so to speak.

The feature articles in SILICON CHIP are always informative and relevant. Keep up the good work.

Derek Mitchell
Battery Point, Tas.

Comments: 2021 seems very early to expect EVs to become cheaper than comparable traditional vehicles. It's almost 2018 and Lithium-ion batteries are still too expensive for that to happen (NiMH is not a good solution for various reasons). Short-range EVs may become affordable soon but there's no guarantee they will be widely adopted.

For example, the new Nissan Leaf has around half the range of a traditional hatchback at around twice the price. The previous generation Leaf sold just over 100,000 in the USA and around 250,000 globally (2010-2016). There were 360,483 Toyota Corollas sold in the USA last year alone. SC

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30 YEARS OF

It could be said that the SILICON CHIP story commences with the first issue, which hit the streets in November, 1987 – 30 years ago. But in fact, the story really starts quite a long time before that!

In the period between about 1960 and 1980, there were two publications in publisher *John Fairfax & Sons'* stable that were outstanding contributors to the company's fortunes: the Saturday edition of *The Sydney Morning Herald* with its fabled "rivers of gold" (also known as the classified adverts) and a strange (at least to the board's eyes) magazine called "*Radio, TV and Hobbies*" (later to become *Electronics Australia* – and universally referred to by readers, advertisers and staff as "EA").

They were each highly successful for similar reasons: they had no real opposition. If you wanted to place a classified ad, you chose the Herald. If you wanted an electronics magazine (and huge numbers did!), for a long time there was nothing else but EA.

In those days, EA circulation was huge – 50,000 a month – and they were regularly bringing out issues with up to 200 pages – much of it lovely $$$ advertising!

Probably because they didn't really understand it, the powers that be at Fairfax sold *Electronics Australia*, to the Federal Publishing Company in 1984. Not only were the staff uprooted but a whole new structure came into being.

From the staid, arguably cloistered environment they were used to, they viewed the many other magazines owned by Federal as "chaotic".

Many did not even have a printed production schedule or deadline and came out, well, sometime close to their dateline!

The EA staff under then editor Leo Simpson gradually became more and more disenchanted with the operation at Federal, even though EA was still an excellent financial contributor. In fact, at the time Federal management regarded the two monthly magazines *Electronics Australia* and *Truckin' Life* as their "jewels in the crown".

In the meantime, two other monthly electronics magazines had been started – *Electronics Today* (in April 1971) and *Australian Electronics Monthly* – both considered "upstarts" but, by the same token, competing for the same, vital, advertising dollars as EA.

As it happened, *Electronics Today* (or more correctly *Electronics Today International – ETI* – there were several overseas editions) had also been swallowed up by the Federal juggernaut.

There was a joke at the time that every time the Federal Publishing boss went out to buy a sandwich for lunch, he'd come back owning another magazine (and/or a press to print it!).

Despite the best intentions to maintain ETI as a going concern, in time management decided that it was all too hard and ETI would effectively be combined with "EA", producing one magazine instead of two.

AEM had a chequered career but advertisers became disillusioned with their "maybe" publishing dates, making sales campaigns meaningless (more than one issue was missed; others were combined into a two-dateline title). Advertising support dried up and AEM ceased publication altogether.

By early 1987, EA staff had decided their only option was to be the masters of their own destiny – and offered Federal Publishing a management buy-out to the tune of $250,000.

This offer was rejected out of hand, with the then Federal Publishing General Manager apparently quoted as saying "Over my dead body", or words to that effect.

And the same day, Leo Simpson was fired.

With such a resounding "no", the remaining EA staff decided that their only path possible was to launch their own magazine and resigned, en masse, from Federal Publishing. Leo Simpson, Greg Swain, John Clarke and Bob Flynn prepared, over the ensuing months, to launch "SILICON CHIP"

By Ross Tester

Again, when the GM heard about this and, presumably, their plans, he promised to see them "dead and buried".

SILICON CHIP launches

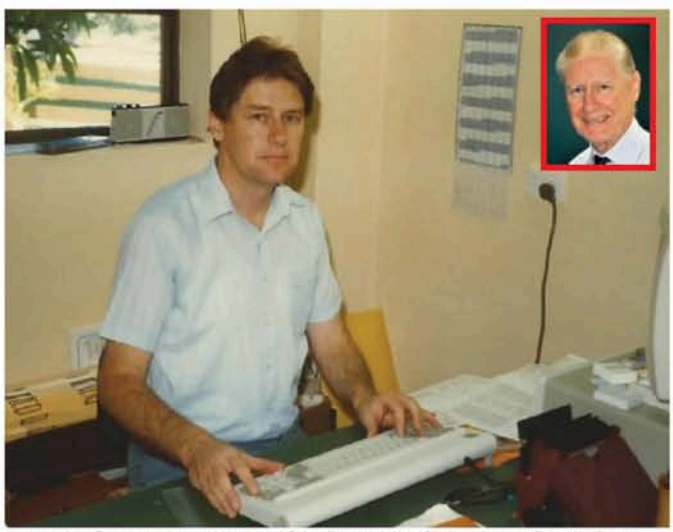
When SILICON CHIP published its first issue in November 1987, it maintained the same strong, authoritative editorial philosophy and content that readers had come to expect from EA. However, even with SILICON CHIP 's acknowledged better content (that came from advertisers in the main) it was extraordinarily difficult to prise readers away from the magazine many had grown up with; the one that had taken them from valves, through transistors and now into the digital age.

But SILICON CHIP persevered and month after month, made enough money to pay staff, to pay the printers and distributors . . . with a little (very little!) left over to continue.

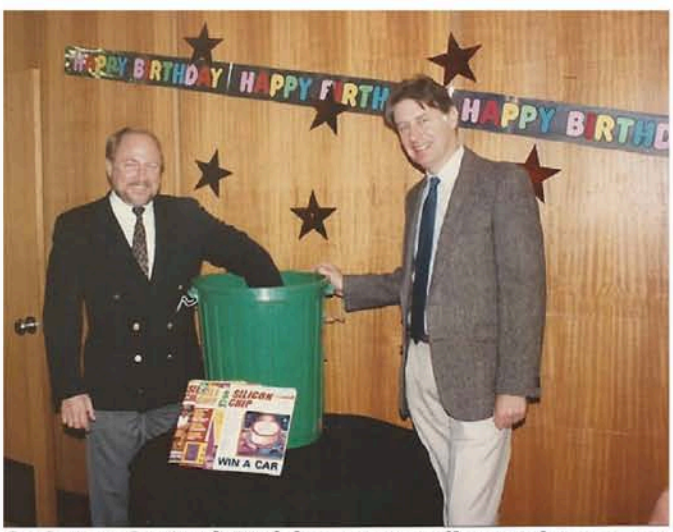
So where did the name come from?

When researching the setting up of a new electronics magazine, Leo Simpson found the market was unbelievably crowded with names involving "Australia", "Electronics", etc. Not all of these involved publications but Leo figured anything using those words or combinations of those words stood a very good chance of disappearing in the market.

Besides, he wanted a name that would be memorable and different. The digital age was starting to become a force in



You might not recognise this hirsute character these days... but then again, this was almost 30 years ago! He's a tad older today; slightly less hair . . . (clue: see the inset!)



On SILICON CHIP's 5th Birthday, we went all out and gave away a CAR to a reader!!!! Here's Jaycar's owner Gary Johnston drawing the winner!

its own right – but even the word "Digital" was hackneyed.

So after much brainstorming and further research, the name SILICON CHIP was decided on and registered as a publication.

eat dies a death

With SILICON CHIP now a legitimate competitor in its own right, (and EA struggling on with several key staff changes) in 2000 Federal Publishing made a monumentally bad call: (arguably again) because they didn't understand why a magazine would need an expensive laboratory, expensive reference books and higher-paid "technical" staff than those that wrote the Dorothy Dixers in their womens magazines – "and what do you need a technical draftsman for when we have artists on staff?". Federal decided they wanted *ea* (now it officially had a name change as well, lower case and all) to go more "consumer" oriented, to develop a market on top of the hobbyist and technical readership.

To this end, they imported a couple of hot-shot marketing whizzes from the Old Dart, who completely re-shaped *ea* to become "*eat*". That "hobbyist stuff" was relegated to a few pages "down the back" while most of the now highly glossy magazine breathlessly told all their readers about the latest whizz-bang consumer products coming onto the market.

The problem with this approach was three-fold:

(1) they missed a couple of months, leading to the rumours that it had ceased publication (which, of course, as EA it effectively had!).

(2) the old readership deserted in droves, many cancelling their subscriptions and switching over to SILICON CHIP.

(3) They weren't replacing the old readership because the consumer area of the market was quite crowded anyway.

So *eat* circulation dropped like a stone – and less than a year later it was announced that *eat* was no more!

As an aside, not long after *eat*'s demise Leo Simpson heard on the grapevine that the magazine's assets were for sale: the titles *eat/ea, EA, ETI, Radio TV and Hobbies, Radio and Hobbies* and even back to their ancestor, *Wireless Weekly*; copyright on all the articles, all the back issues, the laboratory (with all its test equipment), reference books . . . everything that was not nailed down.

So Leo Simpson offered Federal's accountants the princely sum of $10,000 – and they accepted! When asked why he bought the remains of the once proud magazine and what he was going to do with the titles, he said "Absolutely nothing! But it made me feel so good to buy everything for ten grand when I had offered them a quarter of a million!"

As owner of all the EA/ETI/RTV&H/R&H copyright, SILICON CHIP continues to make occasional sales for readers wanting reprints of old articles, PCB patterns (where published) and so on. Naturally, with these magazines going back into history (way before computers!), electronic files are virtually non-existent.

Changes in SILICON CHIP production

That brings us to another rather dramatic change which technology has brought about. When SILICON CHIP started, desktop publishing was largely some time off. It was a rather monumental step-up to even type "copy" onto a word processor, as distinct from a typewriter.

But in the early days, the word processor files were sent (via a 300 baud acoustic-coupled modem!) to a company which specialised in "typesetting". There was no such thing as computerised page layout – the files were returned to SILICON CHIP as "galley proofs" – a continuous strip of paper on which the article was printed, to the required column width and in the appropriate "fonts" or type styles. Galley proofs for large articles could easily be metres long!

The galley then went into "paste up" where it was cut up and glued in position on layout sheets printed to the same size as the final magazine size. Allowance was made for any photos, diagrams, etc in the paste-up.

Speaking of diagrams, in the early days they were all painstakingly prepared by the draftsman, Bob Flynn, using pen and ink. Large circuit diagrams and printed circuit board overlays could take, sometimes, days to draw.

Photographs, which had been taken off-site by professional photographers, predominantly in black and white, were scaled to fit the required spaces and these, along with the diagrams, were then despatched to a photo-engraver to not only re-shoot at the right size but in the case of photos, "screened" to produce the dot pattern capable of being printed (the normal magazine or newspaper printing process to this day cannot print continuous-tone photos).

All of the material, page layouts, diagrams, photos, etc, was then despatched to a specialised production house which assembled the pages ready for printing – usually, after quite a lot of back-and-forwarding for corrections, changes, etc.

Finally, the magazine was sent by air to the printer –

Once upon a time, Greg Swain had the reputation for the messiest desk in the company. Then Ross Tester came along and blew that record right outa the water!

Two more SILICON CHIP originals: Bob Flynn, our draftsman (since retired), and John Clarke (who hasn't!). John moved to northern NSW many years ago but is still full time with SC.

originally on Syquest 100MB drives; later, as technology improved, on (wow!) 250MB Iomega Zip disks (usually, it took between six and ten disks to send an entire magazine).

That was then . . . and this is now!

SILICON CHIP is now produced virtually entirely "in house" until the very last stage of the process, printing (which is done on high speed, heatset web-offset presses the size of a semi-trailer!).

Pages are designed and set up "on screen" with an Adobe product called "InDesign". Computer files containing the article text (called copy), digital photos, circuit diagrams and PCB artwork/overlays, along with anything else to go in the article, are all given the InDesign treatment to produce the pages you are so familiar with.

Circuit diagrams and other graphics are "drawn" on screen using "CorelDRAW", using our own component library, built up over many years. Many have asked over the years why we don't use a dedicated CAD program but we have found that, despite its sometimes poor behaviour, Corel gives us enormous flexibility.

One thing that hasn't changed much over the years is the "look and feel" of the magazine. SILICON CHIP believes it is important to make articles as legible as possible so you won't see too much of the "arty-farty" look so many modern magazine creative directors are so enamoured by.

In fact, the typeface used in SILICON CHIP in 2017 articles is exactly the same as that used in SILICON CHIP in 1987. Sure, we now make extensive used of colour (something that was prohibitively expensive back then). But the philosophy is to make articles highly readable, as distinct from pretty (and hard to read!).

We've ignored the "modern" trend to use sans-serif typefaces, simply because research has proved again and again that a serif face – in our case Melior – is very significantly more legible and comprehension is vastly improved. But try telling that to a pony-tailed art director!

For the same reason, we try not to use too many typographic "tricks" such as printing over a photo or coloured background – unless, of course, the photo demands it!

And speaking of photos, our in-house photography has become one of our strengths – with a minimum of equipment (studio flash and a Nikon DSLR camera) we produce some pretty amazing shots. We're sure that many people who take press and magazine photos have never even heard of depth-of-field! We have . . .

Of course, the skill of our people in photography manipulation has just a little to do with that (yes, we use Adobe Photoshop!). And we are constantly congratulated by contributors in the way we are able to turn their "sow's ears" into "silk purses".

Which is all just as well, as one of the hallmarks of the magazine has always been clarity and consistency. We know that our readers are looking for both detail and information; our constant aim is to give it to them!

Another aside: when SILICON CHIP decided to start using desktop publishing in the 1990s, virtually the whole industry used Apple (later Macintosh) computers. Even retailers which sold MS-DOS machines had the ubiquitous Macs in their advertising studios!

Unfortunately, Apples at the time sold for two and three times (or more!) IBM PCs (or their clones) so SILICON CHIP decided to go the IBM/MS-DOS route, in line with the company's "lean and mean" mantra.

When Greg Swain started dealing with the typesetters, the owner (a German who must remain nameless!), said "Nein! It vill not vork. IBM is no goot. You must use Apple." A couple of successful issues later, he expressed his amazement that it did, indeed, "vork"!

Lean and mean

As Leo Simpson commented in the publisher's letter this month (page 4) one of the main reasons that SILICON CHIP survived (where so many magazines and publishers failed along the way) was keeping costs to a minimum.

When the magazine started, it was produced in the basement of Leo's home in Sydney's northern beaches. That was fine with the original "gang of four" (they didn't even have an advertising manager or even a secretary!) but as the operation grew, extra staff became necessary.

So over the ensuing thirty years, SILICON CHIP had to move five times – with barely a day of production lost each time.

The last move (gad, was it really 11 years ago?) was to the company's current building in Brookvale, right in the heart of the Northern Beaches.

We've also changed printers three times – but two of those were to different divisions of the same company as they rationalised their own operations. Originally, SILICON CHIP was printed by Masterprint, in Dubbo (country NSW). When Hannanprint Sydney purchased Masterprint

For quite some time SILICON CHIP couldn't afford a secretary but then it got too much for Leo and he hired Ann Morris – the same Ann Morris who still answers the phone today!

SILICON CHIP has moved five times in thirty years – two of those not really by choice! Here's the third office in Bassett St, Mona Vale – still fondly regarded by those who can remember!

and moved its presses to their plant in Alexandria, SILICON CHIP went with them. Even though they were several hundred kilometres closer, production processes remained much the same.

Further rationalisation by Hannanprint saw SILICON CHIP printing moved to their Noble Park plant in Melbourne, Victoria. But in early 2017, the decision was made by SILICON CHIP (for various reasons, not the least being "lean and mean!") to bring printing back to Sydney – this time to Bluestar, in Silverwater.

Oh, those rumours!

Over the years (and particularly since the days of computer bulletin boards and later forums) we've lost count of the number of times that it has been stated categorically (eg, *my mate works for xxxx and he told me that . . .*) that SILICON CHIP was owned by Jaycar Electronics or Altronics. And even once, we've seen that SILICON CHIP owns Jaycar! (Oh, how we wish . . .).

To set the record straight once and for all, none of this is true. While both Jaycar Electronics and Altronics have supported SILICON CHIP with advertising since the first issue – without which the magazine definitely would have folded – all three companies are completely independent of each other. Capiche?

The Internet

The exponential rise of the Internet since SILICON CHIP started has had two major impacts on the magazine.

The first, and most obvious, was/is our website, **www.siliconchip.com.au** This has itself gone through several iterations – initially it was set up "in house" as a simple source of information for SILICON CHIP readers – including such things as PCB pattern and front panel artwork downloads. Later, an outside company was contracted to significantly expand the site and also offer limited component and kit sales, among other lines.

The final change (so far!) came when we took the site back "in house" and made the on-screen presentation look identical to that of the printed version, with extensive search facilities. Subscriptions are available in either printed or online editions, or both, as readers require.

The other significant advance to the website was brought about by reader demands: they told us that they couldn't build certain projects because PCBs were getting difficult or impossible to buy, and/or as components became more specialised or esoteric, the usual sources did not stock them.

Without wanting to go into competition with our major advertisers (in fact, we discussed it with them first) we made the decision to produce and sell all PCBS and many front panels etc, used for magazine projects (since about 2000), along with hard-to-get components which retailers could not justify putting into stock.

Where the retailers decide not to "kit up" for a SILICON CHIP project (and again, that's usually because they cannot justify the cost of doing so), we sometimes make kits available ourselves, either in "short form" or occasionally full versions.

Most recently, with the purchase of a CAD Laser Cutter, we also have many acrylic cases, front panels etc, available via the SILICON CHIP Online Shop.

The other impact of the internet for SILICON CHIP is completely unseen by readers: it has enabled a quite dramatic streamlining of production processes and tightening of deadlines, because electronic file despatch and receipt is virtually instantaneous.

Where deadlines for advertisers "in the olden days!" used to be around six weeks or so from publication date, it's now around a month – with publication on the last Thursday of each month, deadlines are now the first of that same month.

Internally, that's also meant we can work very much closer to the "on press" date because all pages sent to the printer totally complete. Corrections and amendments are also electronic, and with the printers using the latest publishing and imposition software, revised pages simply slot into place.

SILICON CHIP, like most publications these days, is produced "Computer to Plate" – gone are the days when four huge sheets of film (one for each colour, cyan, magenta, yellow and black) had to be shot and then used to expose light-sensitive plates for the press. Now, the finished pages are sent via computer to produce the printing plates direct.

The future?

Well, that is really up to you, our readers and advertisers.

With your continued support, we plan on being around for another thirty years – and then some . . . though we doubt that too many of the current staff will be here to celebrate that particular birthday! SC

Another of the early SILICON CHIP staff was the late Rick Walters. He brought a "hands-on" knowledge of industry and commercial practice to the company.

Staff photographer, graphic designer and writer Ross Tester wasn't one of the originals: he came along when Leo asked him to work a day or so a month – nearly twenty years ago!

CADEX

The improved

C5100B

With updated

QUICKSORT™ 4:

Rapid 4 Minute Testing
of 500-4000mAh batteries
such as in mobile phones

On-the-spot battery testing is easier and faster than ever thanks to the new and improved ***Cadex C5100B*** Lithium Ion battery analyser, now with built-in **QuickSort™ 4** technology that tests LiIon batteries in a matter of minutes.

Alternative battery testing methods can take up to 10 hours to deliver a result but in three easy steps, the ***C5100B*** uses its **QuickSort™ 4** program to test any 3.6V/3.7V LiIon battery and deliver clear results - *GOOD* or *POOR* - in just 4 minutes!

1 CONNECT THE BATTERY

2 SELECT THE RATING

3 PRESS PROGRAM KEY

QuickSort™ 4 is capable of testing LiIon batteries from 500mAh up to 4,000mAh - a versatile range which easily covers most batteries for mobiles and smartphones, digital cameras, bluetooth and wireless headsets, two-way radios, medical applications and many more.

In just 4 minutes, from the retail store counter to the back of a warehouse, any user can now quickly assess whether a given battery has run its course or if it's actually the device that is faulty and take appropriate action, vastly improving customer care while saving time and money.

The C5100B features FOUR programs to choose from:

- ***Test:*** 4 Minute **QuickSort™ 4** test for LiIon batteries
- ***Charge:*** provides full charge in approximately 3 hours
- ***Cycle:*** Charge / Discharge / Charge to determine true capacity with capacity readout in mAh
- ***Boost:*** Revive overdischarged batteries

TEST	CHARGE	CYCLE	BOOST
Checks the battery in just 4 minutes	Charge the battery in approximately 3 hours	Charge / discharge / charge and readout in %	Revive over-discharged batteries

How can Cadex C5100B help you?

Quickly determine the State of Health (SoH) of batteries:

- In a new batch to verify quality
- In an existing fleet for effective fleet maintenance
- In the shopfront for fast, conclusive problem resolution

Options and accessories

Purchase the ***C5100B*** kitted with a Universal RigidArm™ adaptor (pictured above) or choose the ***C5100B*** unit only and select from a great range of optional adaptors to suit a specific battery model.

Available for free download is the **BatteryStore™** software which unlocks functions to test 7.2V/7.4V LiIon batteries.

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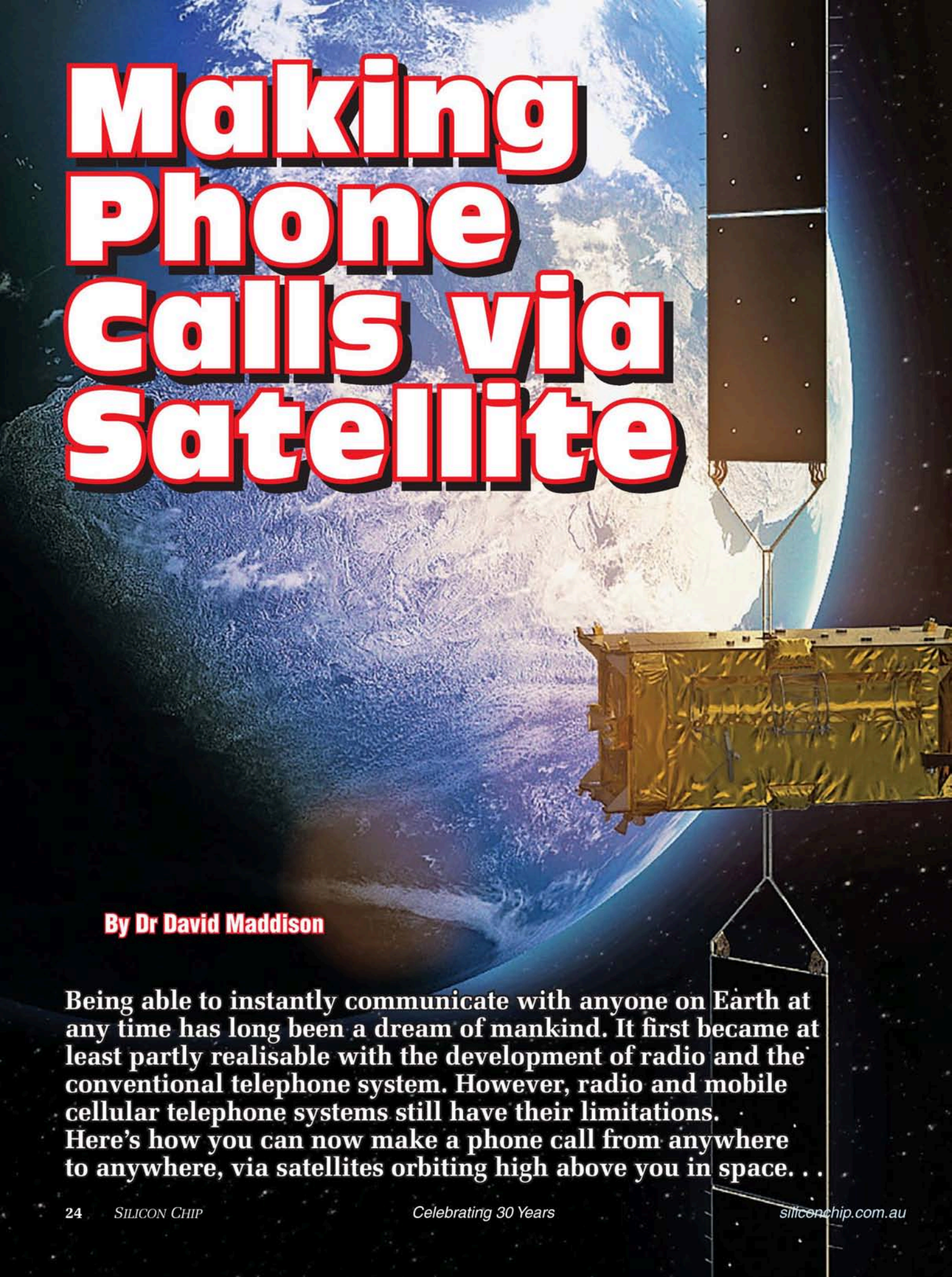
March 2017

Making Phone Calls via Satellite



By Dr David Maddison

Being able to instantly communicate with anyone on Earth at any time has long been a dream of mankind. It first became at least partly realisable with the development of radio and the conventional telephone system. However, radio and mobile cellular telephone systems still have their limitations. Here's how you can now make a phone call from anywhere to anywhere, via satellites orbiting high above you in space. . .

THE ULTIMATE COMMUNICATIONS SYSTEM is one in which each person has their own small, wireless, handheld personal communications device which will work anywhere on Earth at an affordable cost – and preferably offering high speed data transfer with Internet connectivity.

Conventional mobile phones come close to this ideal but can only work within the limited range of a cellular tower. With 4G cellular service, this might be several tens of kilometres under ideal conditions but much less in common scenarios.

In a large country like Australia or in undeveloped countries it is simply not economically feasible to install base stations in enough locations to offer universal coverage. Nor is it possible to have base stations at sea, nor base stations continuously accessible by aircraft, so other solutions are necessary.

As early as 1945 Arthur C. Clarke recognised the problems of the limited range of central radio transmitters and proposed a system of orbiting "rocket stations" (or satellites as we now know them) to provide global coverage of radio broadcasts.

You can read his original article titled "*World Extra-Terrestrial Relays – Can Rocket Stations Give Word-wide Radio Coverage?*" from the October 1945 Wireless World at siliconchip.com.au/l/aaeo

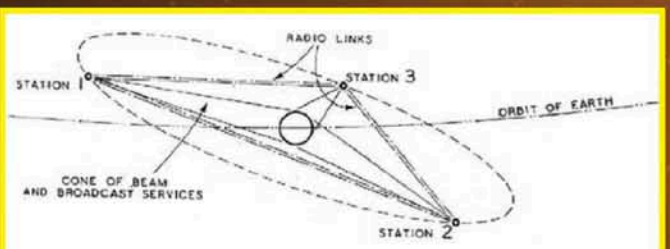


Diagram from Arthur C. Clarke's 1945 article showing how three orbiting geosynchronous satellites could provide global radio coverage. The satellites would also be able to communicate with each other. The first maritime telecommunication satellite system, Marisat used this scheme when its three satellites were launched in 1976.

Geostationary vs LEO orbits

Satellites can be placed into two possible orbital configurations: geostationary, where the satellite will appear to remain at the same point above the Earth; or low Earth orbit (LEO), where the satellites move rapidly and can only maintain contact with a particular point on the Earth for a limited time, usually just a few minutes.

To provide global or close-to-global coverage, at least three or more geostationary satellites are required – or a much larger number of LEO satellites.

In the case of LEO satellites they must be able to hand over any existing radio link to the next satellite that will become visible to a linked Earth station (eg, a phone).

Some satellite phone systems don't aim for global coverage but only regional coverage so fewer satellites are needed.

Geostationary satellites orbit at an altitude of 35,786km above the Earth's equator and their orbital period is the same as the Earth; thus they appear to be stationary to a ground observer. Any fixed satellite dish you see will be pointing at such a satellite.

There are several disadvantages of these satellites for telephony. One is that there is a noticeable delay in speech due to the great distance the radio signal has to travel (each leg of the trip takes around 0.12 seconds or 0.24 seconds round trip).

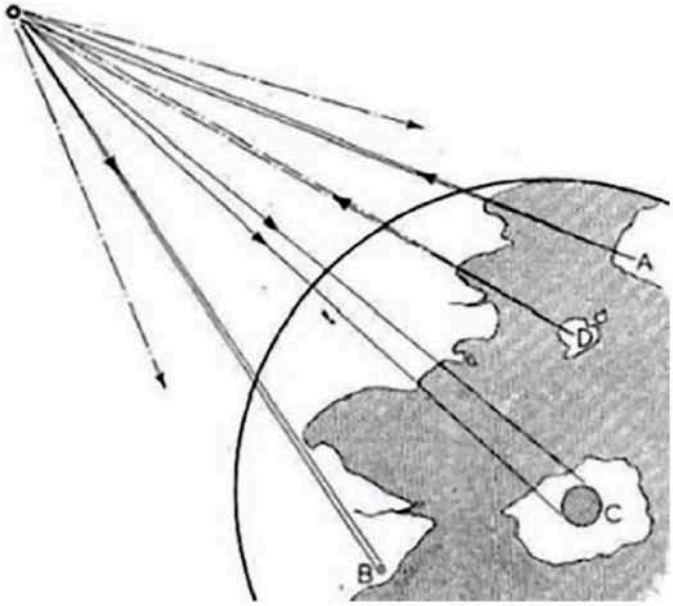
Also, compared with LEO satellites, a larger amount of transmitter power is required in both directions due to the greater distance.

The line-of-sight between the Earth station and the satellite can be interfered with by objects such as buildings, trees or geographical features.

The Earth station is also limited to below 70-80° north or south of the equator.

LEO satellites typically orbit at an altitude of between 640 and 1120km, giving an orbital period of 1hr 37m to 1hr 47m and a velocity of 7.5 to 7.3km per second respectively. For an altitude of 760km, which gives a 1hr 40min orbital period, a coverage cell on the ground of around 2800km

On these pages: an artist's impression of Inmarsat's Alphasat, one of four satellite phone providers available in Australia. This image does not convey the huge size of this satellite with the solar array spanning 45m and the antenna some 9m in diameter.



Another diagram from Clarke's article showing "extra-terrestrial relay services". The direction of the arrows represent uplinks or downlinks.

dius can be provided. A typical link with a ground station (phone) will last from about 4-15 minutes depending on the relative position of a satellite and ground station.

Consider the cell of 2800km radius mentioned above, that would be traversed in about 12.5 minutes at 7.47km per second, the orbital velocity of a satellite at 760km altitude. The round-trip delay for that LEO satellite is *very* much shorter than geostationery– just 0.005 seconds (compared to the 0.24 seconds mentioned earlier).

However, since LEO satellites do not remain in the same place, they must be in placed in orbit in communication with each other so a link can be seamlessly handed over to the next satellite that comes into view and the views must overlap to prevent the call being lost or interrupted.

Satellite phones

There are several satellite phone systems currently in use, with more on the horizon. Systems which use geo-synchronous satellites include those provided by AceS, Inmarsat, Thuraya, MSAT/SkyTerra, Terrestar and Pendrell Corporation (yet to be placed into service). Systems which use LEO satellites are provided by Globalstar and Iridium.

Satellite phones operate in the "L" band which is defined by the Institute of Electrical and Electronics Engineers (IEEE) as the band from 1GHz to 2GHz.

Iridium phones operate in the range from 1616MHz to 1626.5MHz; Inmarsat phones operate in the range from 1525MHz to 1646.5MHz; while Thuraya phones use the range from 1525MHz to 1661MHz.

Compare this with land-based mobile phones which operate in the 800MHz to 900MHz and 1800MHz to 1900MHz bands (although there are other bands coming on line as other services are moved).

Note that while the L band is used for mobile uplinks and downlinks, the satellites may use other bands for control and management purposes and for communicating with their companion satellites.

Satellite phone physical format

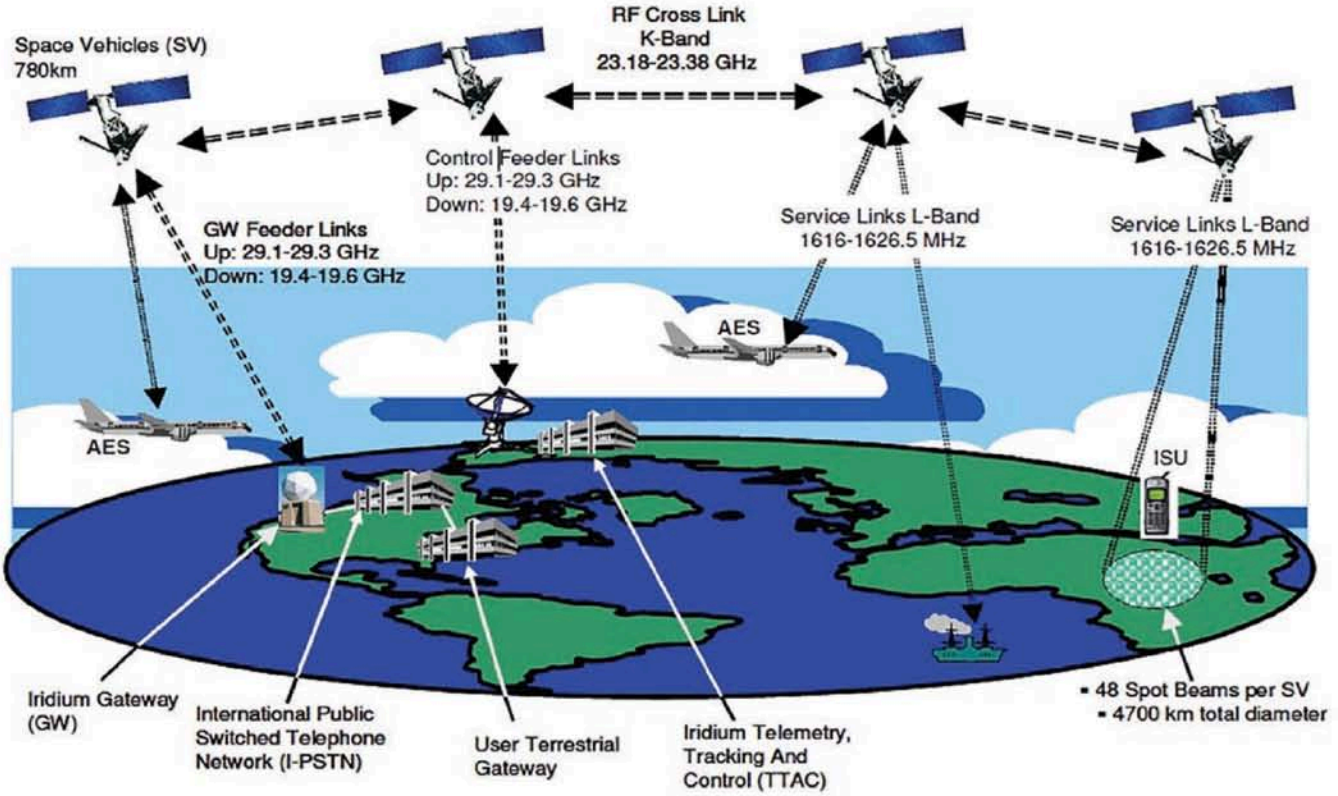
Portable satellite phones come in three main physical forms.

These are: a standalone handset, which is usually larger than a modern mobile, mainly because of the relatively large external antenna; a separate "hot spot" device that wirelessly connects to a standard mobile and uses dedicated Apps on the mobile; or a "sleeve" into which a standard

Iridium Extreme 9575 handset. It is compact, rugged, water and dust resistant and offers four hours talk time and 30 hours standby time.

Inmarsat IsatPhone 2 handset. This phone is said to register onto the satellite network within 45 seconds and also has a standby time of 160 hours and a talk time of eight hours.

The Thuraya Satsleeve+. It clips to the back of a smartphone and establishes a wireless connection. The phone (with the appropriate App) acts as the user interface. A dedicated model for the iPhone also plugs in via the phone's Lightning connector.



Operational scheme for Iridium. The abbreviation AES stands for Aircraft Earth Station and is for communications between an aircraft and the satellite while ISU means Iridium Subscriber Unit, for a handset or modem. Note the communications links between the satellites.

smart phone is inserted and like the hot spot device, uses dedicated Apps on the phone. In addition to these devices, there is also a wide variety of dedicated marine, data and other products.

Antenna systems

One challenge of satellite phones designers is to provide a highly efficient antenna in a small package. Arguably, it is one of the most important elements of a satellite phone.

Inmarsat Wideye iSavi terminal for the Inmarsat IsatHub service. The IsatHub service offers stated data speeds of 240kbps uplink or 384kbps downlink, a high quality voice line and ability to send texts, emails and access the internet. It can be connected to an iPhone or Android mobile phone.

One type of antenna used as an external antenna for Iridium phone equipment is a "hockey puck" style and has a gain of 3dBic (dBic is gain over isotropic, circular polarisation), 50 ohm impedance and uses right hand circular polarisation.

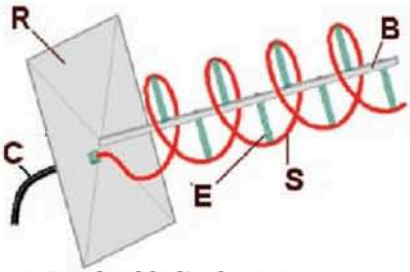
Another antenna type used for Iridium handset devices is the 14mm by 33mm Maruwa MWSL-3105 dielectric-loaded decafilar-helix (containing ten radiating helical elements which we will discuss shortly) which provides excellent beamwidth (>135°). Its gain is 2dBic at the zenith and it has a 50-ohm impedance.

Circular polarisation of the radio signals means that for each wavelength, the plane of polarisations rotates through 360° in a corkscrew fashion and energy is radiated in all planes between horizontal and vertical.

It is like having a "spinning" traditional dipole antenna (this analogy will be important to recall later).

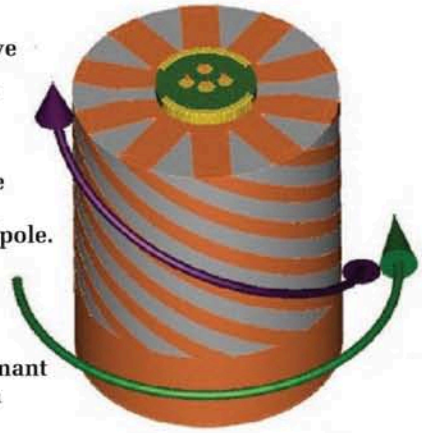
This is in contrast to traditional linear

Globalstar's Sat-Fi will provide a satellite-connected "hot spot" for your mobile device when out of cellular range.



A standard helical antenna design. B and E are support structures, S is the helical radiating element, R is the ground plane and C is the feedline. Author: Ulfbastel

Maruwa antenna with cover as used in Iridium devices. It is designed to produce signals with right hand circular polarisation.



Murawa deca-filar antenna. There are five pairs of helices, with each adjacent pair of helices having a phase-shift between them to synthesise the effect of an upward travelling spinning dipole. The green arrow is the direction of the current around the base and the purple arrow shows the resonant wave travelling up an individual helix.

polarisation produced by a dipole antenna which radiates energy in one plane only. Typically the polarisation is vertical, requiring vertical antennas.

Circularly polarised signals are less dependent on antenna orientation and they are better at penetrating obstacles such as trees, buildings or even adverse weather.

Circularly polarised signals can be either left or right-handed, which varies per carrier; Globalstar left, Inmarsat right, Iridium right, Thuraya left.

There is no particular advantage for either polarisation except one might be used over another to avoid interference with nearby emission sources, in which case one would choose the opposite polarisation to the nearby source.

A problem with traditional circular-polarised antennas is that a signal is emitted from both above and below the antenna, one signal right-hand and the other left-hand polarised, representing wasted energy.

The problem is solved by using a ground plane, which acts as a "mirror" and changes the polarisation of one signal and reflects it in the desired direction.

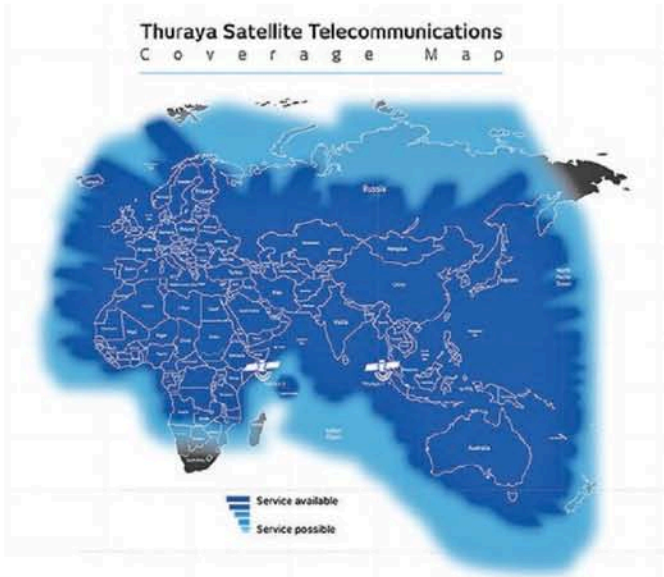
However, the ground plane has to be about one quarter of the signal wavelength (which would mean a ground plane of around 4.6cm diameter for Iridium signals) which is difficult because the phone has to be as compact as possible.

The Murawa multi-filar (it contains multiple helical elements) antenna solves the problem of a ground plane – in fact it eliminates it, by producing a corkscrew radiation pattern that travels up the antenna. It uses multiple pairs of helical elements with a different phase between sequentially activated adjacent pairs.

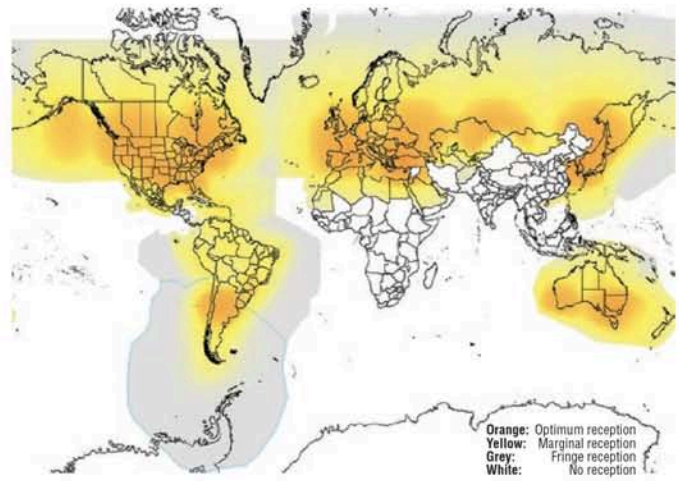
These suppress the reverse-going wave by allowing the signal to propagate only in the desired direction since a reverse-going wave will be cancelled with an additional wave going in the desired direction that is generated by the next helical pair.

In the deca-filar antenna used for Iridium applications, there are five pairs of helical antenna elements.

The physical structure of the Murawa antenna is in the form of a metal pattern printed onto a low loss dielectric base. The lower metallised part of the structure forms a sleeve balun (a type of transformer, to connect a balanced load to an unbalanced load). This serves to isolate the antenna radiation from the ground plane of the device, so that antenna resonance is independent other structures in



Coverage area for Thuraya. Note that it is not global but services most of Africa, Europe, the Middle East and South East Asia. The area is serviced by two geostationary satellites, Thuraya 2 and 3. Thuraya 1 was defective and was parked in a junk orbit and permanently retired.



Globalstar coverage map for voice, duplex data and Sat-fi. Sat-Fi is a Globalstar product which which establishes a satellite link and also connects via a Wi-Fi link to any device running Globalstar Apps such as a smart phone or other suitable wireless device. This enables it to make voice calls and send and receive SMS messages or establish a data connection. It is like a wireless hotspot for your phone but the wireless router connection is replaced with a Globalstar satellite connection.

	IRIDIUM	GLOBALSTAR	THURAYA	INMARSAT
Satellite orbit	LEO	LEO	Geostationary	Geostationary
Coverage	Total global coverage	Not global due to smaller constellation than Iridium. Australian coverage can be limited in the far north – just need to wait until the satellite is in view.	Not global, selected geographical coverage but available Australia wide.	Global except for latitudes higher than 82° (ie, no polar coverage).
Handset features	Small, rugged.	Small, low cost. Rugged handsets available.	Small, sleeve concept available for smart phones. Rugged models available.	Medium cost. Rugged handsets available.
Data available	2.4kbps uncompressed on handset, 1.5Mbps or 8Mbps on data terminals.	9.6kbps uncompressed, on handset with kit.	60kbps down 15kbps up on handset and 144kbps with terminal.	2.4kbps on handset and 492kbps with BGAN terminal for standard IP data.
Example cost of voice call from one Australian provider	40c to 99c *per 30s* plus 40c flagfall plus $40 to $99 monthly fee.	80c to $1 per minute plus monthly fee of $20 to $70.	80c to 99c per minute plus $15 to $65 monthly fee.	40c to 75c per minute for outgoing calls plus 40c flagfall plus $40 to $99 monthly fee.

Table 1: comparison of various satellite phone systems. According to one Australian dealer that sells phones for all these networks, the overall plan costs from cheapest to most expensive are Thuraya, Globalstar, Inmarsat and Iridium. Notably, the two cheapest systems offer the most limited coverage and the two most expensive offer near global or global coverage. Data rates available depend on various options selected. Note also that faster speeds are often quoted but these figures are for compressed data. Costs are examples only; like all mobile plans, a detailed comparison should be done for your circumstances.

the housing or unwanted loading caused by the body of the person holding it.

Networks available in Australia

The four satellite phone networks commercially available in Australia are Globalstar, Inmarsat, Iridium and Thuraya. Iridium gives global coverage, Inmarsat is near global coverage except polar regions while Globalstar and Thuraya are for specific regions.

Inmarsat was founded in 1979, then Globalstar (original company founded 1991, restructured 2003), followed by Thuraya in 1997 and then Iridium (original service launched 1998, bankrupt 1999, company restarted 2001).

These dates don't necessarily reflect these company's offerings for handheld satellite phones however. Iridium introduced a handset in 1998, Globalstar in 2000, Thuraya had a limited service from 2001 and Inmarsat introduced a handset in 2006.

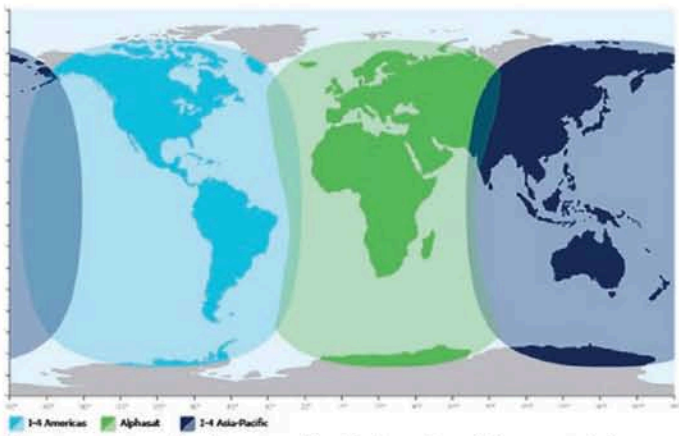
All services have specific strengths, weaknesses, coverage areas and costs (as of mid-2017) – see Table 1.

Iridium

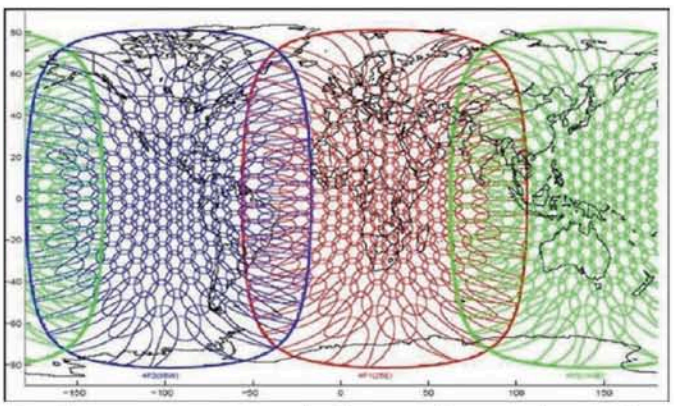
Iridium were the first company to offer handheld satellite phones in 1998 although the company soon went bankrupt in 1999 due to the high cost of handsets, the call costs and poor management.

Originally, the bankruptcy meant that the unused satellites would have to be de-orbited so they did not take up valuable orbital slots but this fortunately did not happen, mainly due to the efforts of one man, Dan Colussy.

The retired former President of Pan Am put together an unlikely group of investors and purchased the assets of



Coverage map for Inmarsat's Alphasat and Inmarsat-4 satellites whose purpose is to cover the main landmasses of the world. Only the Arctic and Antarctic areas above about 82° are not covered.



Spot beam coverage areas for Inmarsat's geostationary I-4 series satellites. Each colour represents a different satellite. The satellites are part of Inmarsat's BGAN Broadband Global Area Network and offer data rates of up to 492kbps to the highest capacity ground terminals.

the bankrupt company at a bargain price of US$35 million (original cost US$6 billion!) and relaunched it in 2001.

(See the panel elsewhere detailing the book "Eccentric Orbits – the Iridium Story", described as a "*monumental piece of nonfiction*" and "*high scientific journalism, exciting business journalism and a rattling good tale.*")

Iridium was originally intended to have 77 LEO satellites – which happens to correspond to the atomic number of iridium, hence the name. However, it was found that only 66 satellites were needed, although spare satellites are kept in orbit.

Iridium satellites are in polar orbit and occupy six orbital planes. Each of the satellites communicates with up to four neighbouring satellites in the constellation, two in the same orbital plane and two in adjacent orbital planes – one to the front and one to the rear.

The current satellites are being replaced with Iridium NEXT satellites which will provide superior features such as more bandwidth and higher data speeds. The new satellites will be backwardly-compatible with existing ones ensuring there is no loss of service and existing equipment can be used.

The NEXT satellites that replace the existing ones will also consist of a constellation of 66 satellites and will have 6 in-orbit spares and 9 on-ground spares. They will offer voice at 2.4kbps and data speeds of from 128kbps to 1.5Mbps on L band and up to 8Mbps on large transportable or fixed terminals using Ka band (19.4GHz to 19.6GHz downlink and 29.1GHz to 29.3GHz uplink).

An additional feature of the Iridium NEXT satellites is they can carry third party "hosted" payloads (see box).

Argo buoys (see SILICON CHIP July 2014 – www.siliconchip.com.au/Article/7932) use Iridium communications to transmit their data. Iridium technology can also be built into devices such as wildlife tracking collars.

Globalstar

Globalstar consists of a constellation of 24 LEO satellites which provide coverage of up to 80 percent of the Earth's surface (excepting polar regions and oceanic regions for

True global tracking of aircraft with ADS-B via Iridium NEXT satellites

Aireon is an example of a hosted payload that is being fitted to Iridium NEXT satellites.

It is a space-based aircraft tracking system which will provide global tracking of aircraft in near real-time using ADS-B (Automatic Dependent Surveillance-Broadcast), a tracking system fitted to aircraft that automatically transmits GPS coordinates, airspeed, direction, aircraft identity and other information from on-board systems.

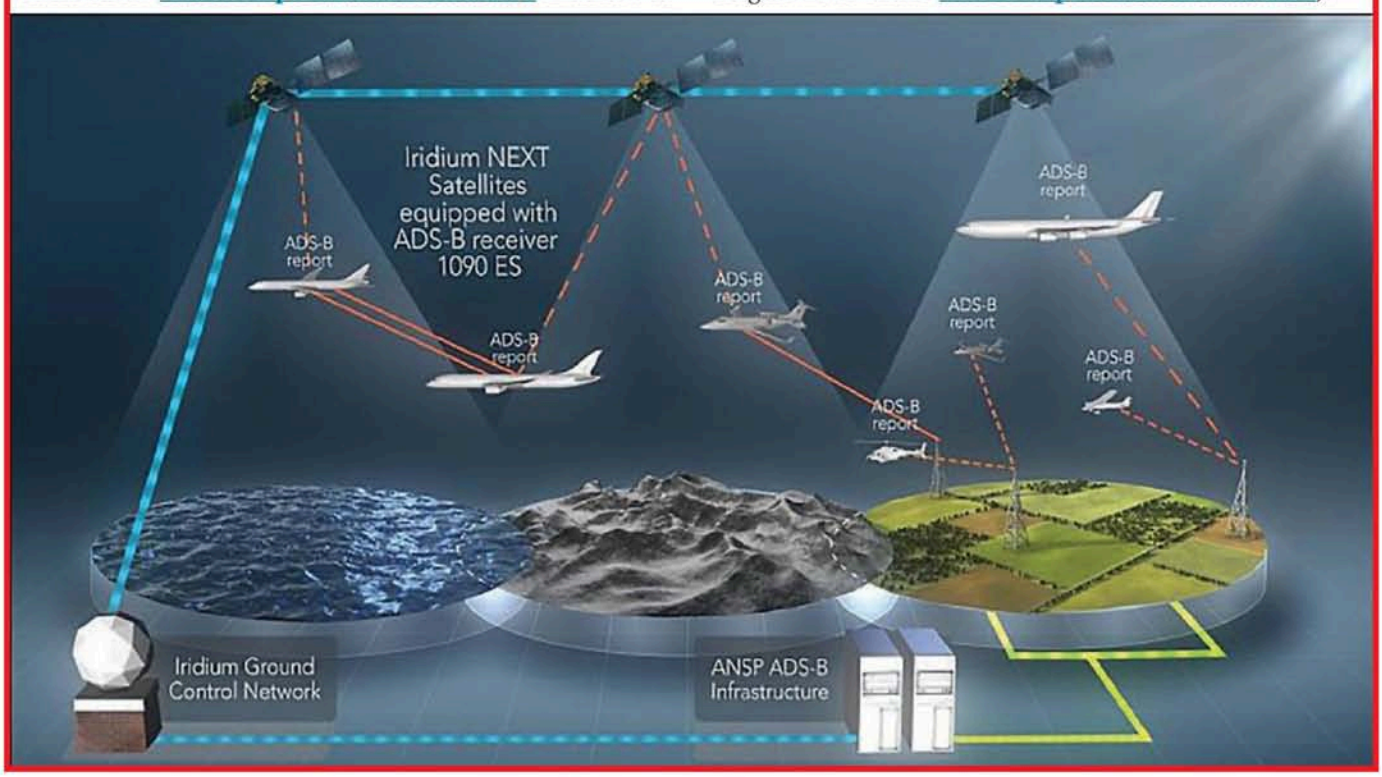
ADS-B already exists on most commercial aircraft and many private aircraft – and is in fact now mandatory in the airspace of many countries. It even has anti-terrorism features built-in, where that can be a problem.

(See the fascinating feature on ADS-B in the August 2013 issue: siliconchip.com.au/Article/4204 and how to use it in conjunction with flightradar24.com).

The problem is that the radio frequency used, 1090MHz, is limited to line-of-sight and coverage depends on the aircraft altitude, distance to the ground receiver station and terrain and weather conditions.

Aireon doesn't replace the existing ground-based ADS-B receiver network but augments it, with space-based receivers to achieve true global coverage.

(Incidentally, as well as viewing ADS-B data from anywhere in the world on your computer, you can receive ADS-B signals themselves, in your local area, with a bit of hardware and software. See how to build one yourself at low cost using a cheap USB DVB-T dongle, also in the August 2013 issue: siliconchip.com.au/Article/4209).



Oops! Iridium satellite collision

In 2009 an operational Iridium (number 33) satellite collided with a retired Russian military communications satellite, Kosmos-2251, that had never been deorbited.

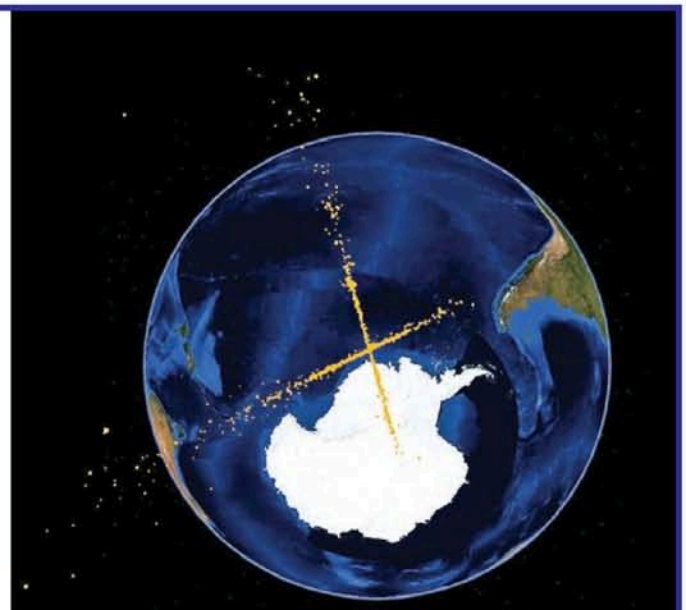
The impact occurred at a combined speed of 42,120kph or 11.7 kilometres per second. Around 2000 pieces of debris larger than 10cm resulted from the collision and in 2011 the International Space Station (ISS) had to perform an avoidance manoeuvre. As well, the Chinese were concerned about debris hitting some of their satellites.

In 2012 debris again came near the ISS and astronauts temporarily took refuge inside Soyuz capsules until it passed. Software designed to track satellite orbits had predicted that they should have missed each other by just 584m.

Such events are rare but emphasise the importance of deorbiting unused satellites or placing them into "graveyard" orbits.

Here is a video of a simulation of the collision: "*Iridium 33 and Cosmos 2251 Collision - Evolve Based Debris*" siliconchip.com.au/l/aaf0

Also see "*LLNL TESSA Simulation of 2009 Cosmos+ Iridium Satellite Collision*" siliconchip.com.au/l/aaf1



The calculated debris field 50 minutes after the collision between Iridium 33 and Kosmos 2251. Author: Rlandmann.

simplex data and less so for voice).

When a satellite receives a call from a handset it relays the call to a terrestrial gateway which then directs the call to the fixed or cellular phone network or internet. With Globalstar's second generation satellites, other satellites are able to pick up a call simultaneously and if the first satellite moves out of range, others handle the call.

According to Globalstar the use of terrestrial gateways allows key technology and equipment to be kept on the ground and accessible and integrated to other phone networks, making Globalstar easier to expand and improve.

The technology is referred to as "bent pipe" architecture meaning that the satellite is an analog repeater (like a mirror in the sky according to Globalstar) and can be simple and cheap with the more complex technology of what is essentially a large cellular base station kept on the ground. There are 24 terrestrial gateways around the world each of which can handle 10,000 simultaneous phone calls. Globalstar uses CDMA technology.

Thuraya

The Thuraya system uses two geostationary satellites to offer regional rather than global coverage. In addition to satellite communications, Thuraya handsets can communicate with regular terrestrial networks just like any regular mobile phone and they can do this in a large number of countries due to extensive roaming agreements with other carriers. Thuraya handsets can be in the form of either a dedicated phone or in the form of a "sleeve" which attaches to a smart phone.

Inmarsat

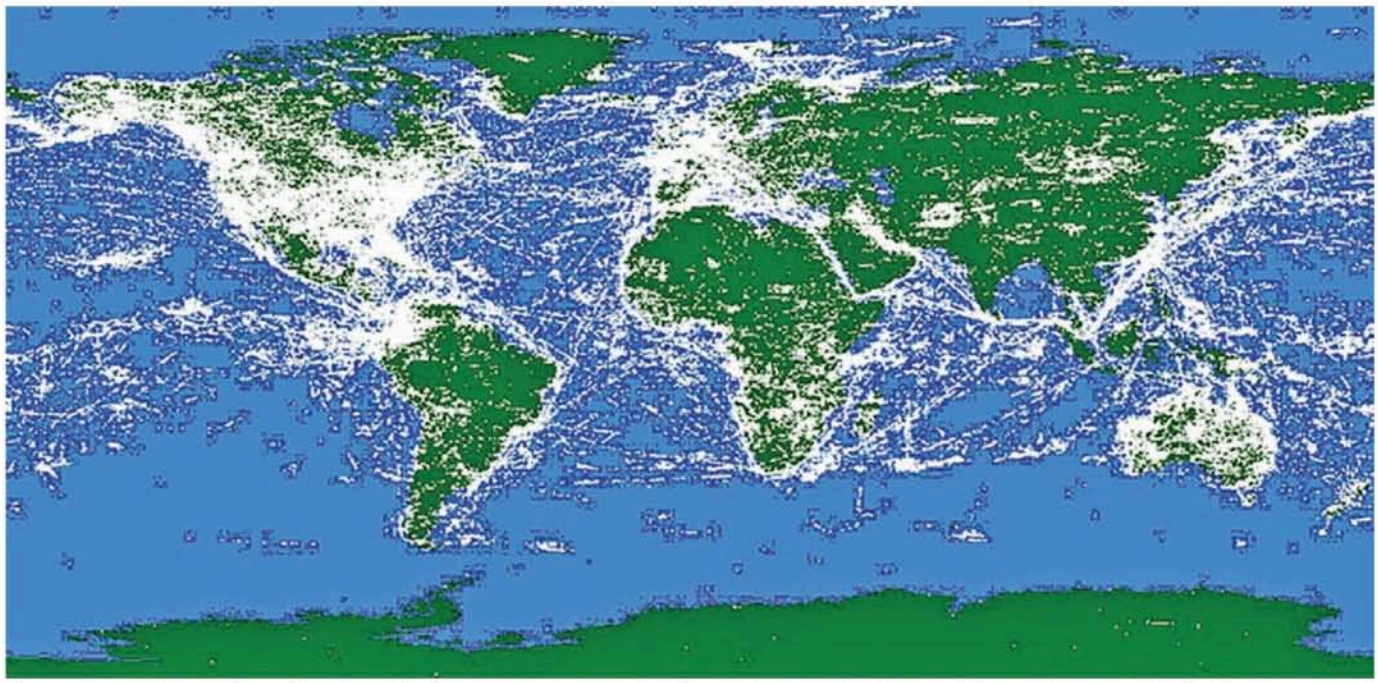
Inmarsat uses 12 geostationary satellites for various services and is global in coverage except for polar regions. It is a well-established network (1979) that was initially offered to maritime operators (hence the name) but now offers a wide variety of voice and data services, including terrestrial, for all types of customers. Coverage is global for voice services except for above 82° latitude.

Mobile handsets such as the Inmarsat IsatPhone 2 mentioned above use the Alphasat and Inmarsat-4 satellite constellation (see coverage map). The Alphasat is a very large satellite with a mass of 6.6 tonnes and dimensions of 7m x 2.9m x 2.3m. Its solar array span of 45m producing 12kW of power for communications, with extra power for hosted payloads (see panel).

Its unfolded antenna reflector is 9m across. It uses chemical and plasma ion thrusters for station keeping.

A notable use of Inmarsat was in the search for missing aircraft MH370. The aircraft used their Classic Aero Service to transmit routine engine information to the manufacturer. While this does not provide location information, rough locations were determined by mathematical analysis of the data.

The Iridium GO! is a satellite hot spot that wirelessly connects to a smart phone or tablet at a range of up to 30m and satellite calls and data are sent to and from the device while the smart device acts as the user interface. Video: "*Iridium GO! Tutorial Video*" siliconchip.com.au/l/aaf3



A usage map for Iridium showing phone usage by location (the white dots) for the week beginning 22nd July 2007. Unfortunately this is the latest such map that Iridium published. Note how major shipping routes are traced out and heavy use in Australia – and also a number of uses from Antarctica. Satellite telephones that use geostationary satellites do not work beyond about 70-80° of latitude so LEO satellites, such as Iridium, are needed in such locations.

Phone number plan for satellite phones

In 1996 the International Telecommunications Union (ITU) assigned a "country code" under the Global Mobile Satellite System (GMSS) number space.

For satellite phones it's normally +881 plus one or two digits depending on which carrier is being used.

For example, Iridium is assigned +881 6 and +881 7. However, Thuraya has been allocated +882 16 which is in the number space for "International Networks", telephone services not exclusively dedicated to a particular country but not generally for satellite telephony.

Presumably, there were no allocations available under the +881 number space by the time Thuraya was launched. Inmarsat, which predates the allocation, had already been assigned +870 to +874.

Particular carriers may elect to provide a country-specific phone number. For example, Iridium in the US provides an Arizona-based number for those people unwilling to dial the expensive GMSS number, while Globalstar provides a local number in the country in which the user is based.

In Australia all available satellite phones using an Australian carrier or provider can be given an Australian 04xx mobile number. If purchasing a satellite phone in Australia, you should ensure that your provider is able to offer an Australian number for the phone of your choice.

Iridium phones have an 8-digit number after the GMSS number, Inmarsat have a 9-digit number and Thuraya have an 8-digit number. To dial the phones directly using their GMSS numbers rather than the local numbers, you would dial the international access code, eg 0011 from Australia, followed by the GMSS number, say 8816 followed by the 8 digit phone number, eg 0011 8816 99393295.

To make a call from a satellite phone when not using the assigned local number you would dial 00 for outbound calls

How resistant are satphones to eavesdropping?

Most security experts seem to be of the opinion that satellite phones do not offer a high level of security against eavesdropping by unauthorised individuals. In 2012 researchers Benedikt Driessen and Ralf Hund managed to break the two common encryption schemes on satellite phones, GMR-1 and GMR-2.

They were able to do this because the phones do not use private keys for their encryption and all that is therefore needed is to understand the mathematical algorithm used.

With a private key encryption scheme you cannot decipher the encrypted data even if you know the algorithm used. Of course, in practice the likelihood of anyone intercepting your call except for the government is likely to be low but it is important to be conscious of the risk.

The report on the encryption weakness *"Don't Trust Satellite Phones: A Security Analysis of Two Satphone Standards"* can be read at **siliconchip.com.au/l/aaep**

Hacking Iridium

A presentation was given at the Eleventh Hope conference in 2016 on security issues with Iridium and how the claimed high level of security arises from the complexity of the system rather than specific security protocols that have been implemented.

It showed how they reverse engineered the data structure of Iridium which was not publicly documented and gained great insight into the workings of the system. Signals were received with RTL-SDR or HackRF/Rad1o.

Of course, what they did may not be legal depending on jurisdiction.

Their video of the talk including a demonstration of connecting to a "secure" telephone line of a C-37 aircraft of the US 310th Airlift Squadron and some very high level technical information is at *"Iridium Satellite Hacking - HOPE XI 2016"*: **siliconchip.com.au/l/aaez**

Hosted payloads on Iridium NEXT and Inmarsat

Of the satphone providers, Iridium NEXT and Inmarsat's Alphasat are able to accommodate a third party "hosted payload".

A hosted payload is a semi-independent piece of hardware attached to the satellite such as a sensor or instrument of some kind that uses the host satellite for a "piggyback" ride into space.

It will typically use the host satellite's power supply and transponders for power and to send and receive data.

Advantages of hosted payloads include:

- a shorter time to get the payload into space as a launch vehicle does not have to be organised and there are many available launches
- lower launch costs as the launch vehicle and other launch facilities are shared
- the possibility of more resilient infrastructure because instead of one satellite with a lot of capabilities, a larger number of hosted payloads each with a lesser number of capabilities can be used and a failure of one unit will not cause total loss of the system.

One example of a hosted payload is a UHF communications payload of the Australian Defence Force that is on the Intelsat 22 spacecraft.

Others include those for laser communications and a Ka band downlink for data link speeds of up to 2Gbps, Q (33GHz to 50GHz) and V (40GHz to 75GHz) band propagation experiments, flight testing of a star tracker and environmental sensors on Alphasat.

Aieron (see separate panel) is another hosted payload to augment the existing ground-based ADS-B global aircraft tracking system with satellite-based receivers to cover "black spots".

Iridium NEXT satellites can carry one large hosted payload or a number of smaller ones. A total payload mass of 210kg can be carried and a total of 650W of power is available with an 1100W surge while a combined data rate of 1Mbps with 10Mbps surge is available.

Whether a LEO or a geostationary satellite is chosen as the host platform for a payload is dependent upon the specific application.

followed by the country code, area code and phone number. You dial the country code even if you are in that country.

Apart from a GMSS number and a local Australian mobile number that may be provided by an Australian carrier, ACMA (the Australian Communications and Media Authority) have also allocated the following number prefixes for Australian satellite phones: 0141, 0142, 0143, 0145 and 0147, each of which are followed by the six digits identifying that particular phone.

When dialling from a satellite phone to a local Australian number with area code, you would dial numbers the same as you usually do, except you would include the area code (even if within that area code's calling zone). For others to call that satellite phone they would simply dial the assigned local number.

Note also that in Australia, if you have a standard satellite number (such as from an overseas carrier) you will not be able to call 13 or 1300 numbers, 1800 numbers or emergency numbers in the normal way and perhaps not at all.

This could negate one of the main reasons people, especially travelling in the outback, buy a satellite phone in the first place.

Emergency calls from satellite phones

It is mandatory for all satellite phones sold **in Australia** to support dialling of the Australian emergency number. In Australian territory (except Antarctica) and territorial waters out to 200 nautical miles, emergency calls go via an Australian operator.

Outside of the Australian mainland but in territorial waters the Australian Maritime Safety Authority would typically be involved in an emergency call and rescue. Outside of territorial waters calls are expected to be handled by the service provider, who will pass the call to the appropriate authority for the area.

An international inbound roamer in Australia could dial 112 for emergency calls but it is possible that their carrier will also support 000 calls as operators try to keep phone firmware updated and consistent with regional standards. Emergency operators will generally receive a three digit code giving the rough area of the originating call based on maps of "standardised mobile service areas" but these areas are quite large.

Most handsets (such as Globalstar) can give a rough location fix, with a maximum 20km radius of error based on triangulation while Iridium, Thuraya and Inmarsat can give an even-more-accurate GPS fix from phone handsets.

Unlike terrestrial mobile phones, which are all built to the same hardware standards and which for an emergency call can connect to any available mobile phone carrier's tower even if out of range of their own carrier, satphones use different technology standards and can **only** connect to the satellite system that the phone handset is designed for.

Debunking a dangerous myth!

There is a widely-held belief that if you dial the 112 emergency number from a terrestrial mobile phone (ie, a standard mobile) that it will automatically connect to a satellite if you are out of range of a tower.

This is simply not true. If you are out of range of a mobile (cellular) phone tower, a non-satellite mobile phone cannot connect to a satellite and make any call – emergency or otherwise.

What are "Iridium Flares"?

Iridium flares are flashes of sunlight reflected from the older Iridium satellites (but not from Iridum NEXT). The web site at siliconchip.com.au/l/aaf5 can be used to predict Iridium flares (and other things) plus there are phone Apps.

Interesting videos and web pages

All links in **Silicon Chip** are quicklinks to save you the hassle of keying-in (and making errors in!) sometimes long URLs. In the **Silicon Chip** online edition they are all direct one-click links.

Using an Inmarsat phone in the Outback
"Immarsat Satellite Phone Video" siliconchip.com.au/l/aaeq

Real-time tracking by an earth station with dish antennas following Globalstar satellites. (Note that this is a fairly uneventful video but you do see the antennas moving as they track the satellites). This earth station is located in outback WA, about 770km NE of Perth. *"Meekatharra Globalstar Satellite Teleport – for satphones"* siliconchip.com.au/l/aaer

A teardown of a 2000 vintage Globalstar satellite phone by an Australian blogger, David Jones. He has a lot of other interesting videos on his channel as well. *"EEVblog #721 – Globalstar Satellite Phone Teardown"* siliconchip.com.au/l/aaes

The teardown of an early model Iridium phone: siliconchip.com.au/l/aaet

"Globalstar Overview (2012)" siliconchip.com.au/l/aaeu
"Iridium-1 Technical Webcast" siliconchip.com.au/l/aaev
"The story of Inmarsat I-4" siliconchip.com.au/l/aaew
"Launch of Thuraya-3 Satellite" siliconchip.com.au/l/aaex
"Inmarsat – The Mobile Satellite Company" (corporate video) siliconchip.com.au/l/aaey

The reverse is not true, of course: even if you are within range of a cellular tower, with rare exception (satellite phones specifically designed for two bands) a satphone will not try to connect to a standard mobile phone tower – it will always connect via its carrier's satellite.

The international standard emergency number 112 should get you through to local emergency services wherever you are in the world and whatever phone you are using, as long as you are in range of a tower or appropriate satellite but you should confirm that your operator supports that before going on any potentially hazardous journey.

Spot beams

In order not to waste communications bandwidth by transmitting to areas not in a satellite's targeted geographic area and also to ensure the maximum number of communications channels are available, telephony and data satellites use spot beams.

These are concentrated radio beams using high gain antennas that send and receive signals to and from limited geographic areas.

Iridium's LEO satellites' spot beams move with the satellite but all spot beams and satellite footprints overlap. Each satellite can project 48 spot beams onto the Earth's surface, arranged in three sectors with 16 beams each, each approximately 400km in diameter. The satellite's full 48-beam footprint is approximately 4500km in diameter.

The large number of fast-moving satellites with multiple overlapping spot beams minimises missed connections and dropped calls, since more than one satellite is usually visible from any place on Earth.

Usually it's more than that, with the constellation of interconnected, cross-linked satellites "talking" with other nearby satellites in front, behind and in adjacent orbits.

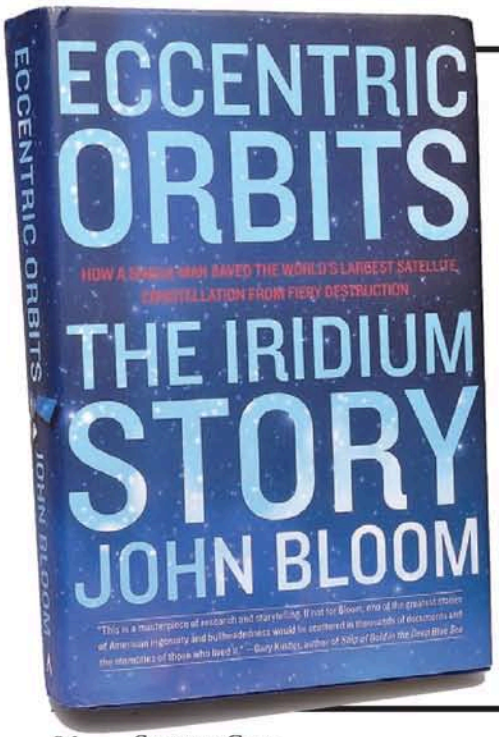
For an animation of how an Iridium satellite's coverage area moves with the orbit of the satellite see siliconchip.com.au/l/aaf4

On the other hand, Inmarsat's I-4 geostationary satellites can each generate 19 wide regional beams and around 228 narrow spot beams.

Geostationary spot beams generally remain in one area on the ground, although they can be moved to a different area if necessary.

Typical ways satellites can alter their spot beam coverage is by switching antennas or electronically steering the beams with phased array antenna technology. SC

Acknowledgement:
The author wishes to the thank Communications Alliance Ltd for information on the operation of emergency numbers from satellite phones.



"A rattling good tale"

Eccentric Orbits, the Iridium Story, by John Bloom

ISBN 978-0-8021-2168-4; Atlantic Monthly Press, New York

It might sound like a pretty dry subject but author John Bloom has managed to turn this (true!) story into a book that you will find very hard to put down.

The title page notes perhaps sum it up best of all: "*How the largest man-made constellation in the heavens was built by dreamers in the Arizona desert, targeted for destruction by panicked executives and saved by a single Palm Beach retiree who battled Motorola, cajoled the Pentagon, wrestled with thirty banks, survived an attack by Congress, infiltrated the White House, found allies through the black entertainment network and wooed a mysterious Arab prince to rescue the only phone line that links every inch of the planet*".

The retiree was former Pan Am president Dan Colussy, who heard of Motorola's plans to scuttle the six billion dollar Iridium project (including all its satellites) and against a huge amount of opposition, managed to revive the project for half a cent in the dollar (just US$35 million!).

The 550+ page "Eccentric Orbits" is available on line from a variety of sources and believe us, once you start reading it you definitely won't stop!

Getting even more from

siliconchip.com.au

As a SILICON CHIP reader (thanks!) you've almost certainly visited the SILICON CHIP website – siliconchip.com.au . . . You may have even spent some time on line, looking for information. But we know that most people use only a tiny fraction of any website – ours included. That's usually because most people don't that know the features they want exist. Here's how to get more – much more – from the SILICON CHIP website. There's a lot more to it than meets the eye!

We published an article on our newly-revised website back in April, 2013 – and as you might expect, we have made a lot of improvements since then. Some of them were issues identified over the years and now "fixed", Some are new features you've asked us for and we've been able to include.

(1) VIEW SILICON CHIP ONLINE ON MOST DEVICES – PC, PHONE, TABLET, ETC

Along with viewing all SILICON CHIP articles online on PCs exactly as they appear in the printed edition, they can be viewed on tablets/phones or on devices without Adobe Flash (eg, on macOS).

It was always our intention to have the online magazine "look and feel" as the printed edition, for familiarity if no other reason. But many (most?) mobile devices, phones and tablets, don't have the Adobe Flash plugin.

The website automatically detects if you don't have this and switches over to an HTML rendering engine for online issues.

In short, this means that you can view any of our online issues on just about any device, as long as the screen is sufficiently large.

Incidentally, we know that Flash support is supposed to be ending within a year or so (it's been annouced many times!) but when (if?) it does, the website will cater for this.

By Nicholas Vinen

Viewing issues is similar, regardless of whether you have Flash or not. For example, when you click on the cover of the current edition that appears on the "home" page (which is the one currently available in newsagents) you will see a list of articles in that issue on the left side.

Hover your mouse over an article name to see a short description. Click on the name to jump to the first page. To change to the next (or previous) page, click in one of the corners of the magazine: the right-hand corners takes you forward one or two pages; the left-hand corners takes you back one or two pages (depending on whether you have one page at view or two).

You can normally also use the left/right or page-up/page-down keys on your keyboard to navigate the issue. If your screen is small or low resolution and you're having trouble reading the magazine, try clicking on the "Fullscreen" button in the lower left corner.

Whether this helps depends on your screen layout; in some cases it can substantially increase the screen area available to the magazine while in other cases it makes no difference. If you're using the Flash plugin, next to the Fullscreen button is a drop-down menu that lets you change between three different display resolutions or switch to the HTML version. Selecting a higher resolution makes the magazine clearer but also means it takes longer to load.

If you have logged in to your account, your preference will be recorded for the next time you view an issue.

The HTML viewer attempts to detect the size of your browser window and optimise the image quality to suit your screen.

If you have a screen in portrait mode, as is common with mobile phones, it should switch to a single-page viewing mode in order to maximise the viewing area of the page. Browsing an online issue via HTML is similar to Flash – you simply click at the left or right edge of the issue to flip to the previous or next spread respectively, or you can click on the name of an article at left to jump to its first page.

One extra thing we should point out is that from time to time, we publish diagrams (especially circuits) rotated by 90° so that they will fit on the page.

Since you can't necessarily rotate your display and rotating your head is quite uncomfortable, in this case, a link should appear to the left of the page to allow you to open a PDF showing the diagram right-way up.

If you have a mouse wheel or equivalent, you can zoom in and out. When you zoom in initially, it may look fuzzy but a higher resolution version should load momentarily, sharpening it up.

Zooming on devices with touchscreens is one of the areas where we plan to improve the HTML viewer in future.

(2) Silicon Chip shortlinks

You've probably noticed that URLs (website addresses) in Silicon Chip articles are now routinely converted to "shortlinks" – a much shorter version which will take you direct to the appropriate page without laboriously re-keying the URL.

These are in the form of **siliconchip.com.au/Link/ABCD** They're real convenient in the printed edition – and even moreso in the online edition, because clicking on any shortlink will take you straight to the webpage referenced in the article.

Hyperlinks which redirect to articles (features or projects) which have been previously published in SILICON CHIP work exactly the same way but are in a slightly different form; eg **siliconchip.com.au/Article/ABCD** will take you to . . . this feature! Hyperlinks within articles should work normally with the HTML viewer.

(3) Links in online adverts

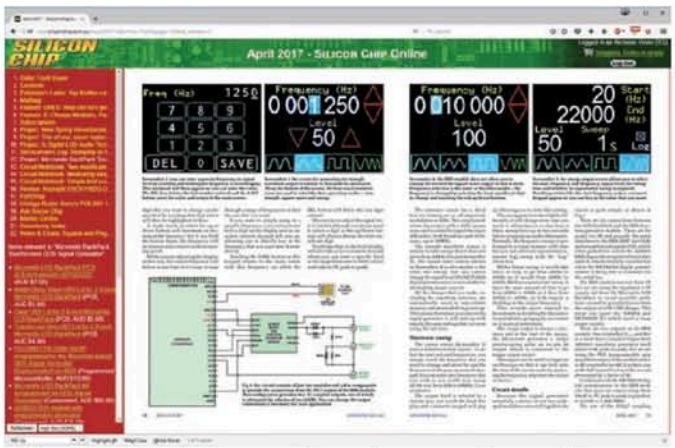
Silicon Chip advertisers are given the opportunity to make any sections of their adverts links in the online edition. If they do this, as you move your mouse over any links, the image will change to the familiar "hand" logo; click on this and you will be taken direct to the product/service being advertised.

(4) Article searches now cover all issues of Silicon Chip

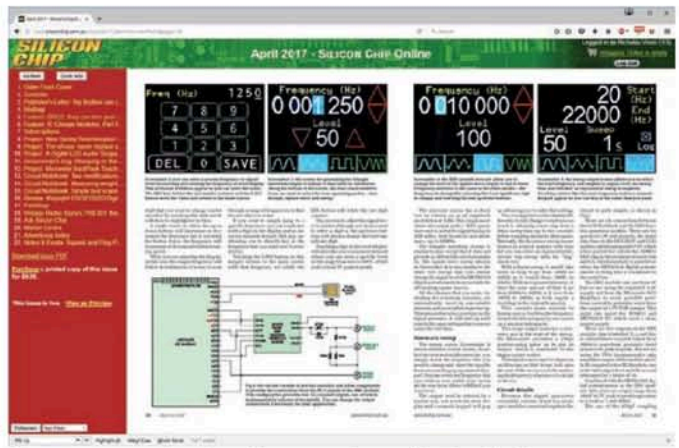
Entering the contents of all issues was an exhaustive process but it is now complete, right back to to the first issue from November 1987 (thirty years ago!). So you can search all Silicon Chip issues in one go.

(See section on "searching" – point 7).

Previous articles referenced are also converted to shortlinks in the form of **siliconchip.com.au/Article/1234**



This screen grab shows us browsing one of our online issues using the Flash plugin. The contents of the issue are shown at left, along with any shop items associated with the article on screen. Note the double-page presentation.



Now we are viewing the same issue (indeed, the same pages) using the HTML version. You can't see the difference in an image this small but it isn't quite as clear. However, it will work on just about any device and browser.

Note though that searching the content of the issues themselves ("Word Search", explained below) is currently limited to issues from May 1997 onward. That's 20+ years of content – keep in mind that components, etc, from that long ago will now be difficult or impossible to obtain.

(5) ARTICLE PREVIEWS

You can view a "preview" of any article from any issue of SILICON CHIP from May 1997 to the present, or from the now out-of-print (but still requested) "*Performance Electronics for Cars*"

To do this, simply click on the "Issues" menu at the top-left corner of most pages of the website (including the front page) and you will see the covers of all the available online issues, along with the month and year of publication and number of pages below. Click on any of these covers to open up a preview of that issue. The first one or two pages of most articles will be visible. For more information on how to navigate through the online issue/preview, see the "Online issue navigation" section below. Viewing "*Performance Electronics for Cars*" is similar – just click on Books.

(6) 20 YEARS OF SILICON CHIP CONTENT

View the cover and contents listing of any issue of SILICON CHIP from May 1997 to the present (not available on devices with touchscreen-only interface).

As above, click on the "Issues" menu to view the covers of the issue and then simply hover your mouse cursor or pen stylus just above one of the covers. After a couple of seconds, a short summary of the major articles in that issue will appear. If you're interested in any of them, you can click on the cover to view the preview, as described in (1) above. This can be a handy way to find an article if you don't know its name but remember the approximate date of publication.

(7) EXPANDED SEARCH PARAMETERS

Search for any project or feature article ever published in SILICON CHIP, based on its title, author, PCB code or other parameters, including some or any of the words contained in that article.

Click on the "Articles" menu near the top-left corner of most pages on the website (including the front page). You will then be presented with a series of checkboxes and entry fields. By default, the website will search all articles. You only need to fill in one of the entry fields below; searching within either the article title ("Name"), its synopsis ("Description"), by Author name ("Author") or a kit or PCB code ("Kits / PCBs").

You can narrow your search to a particular type of article by deselecting some of the checkboxes along the top; to select just one type of article, click the "None" button to the right of the checkboxes to clear them all, then select the one that you want. You can also narrow your search to a particular project or feature article category by selecting that category from the dropdown below the entry fields.

Here's the trick to easily find the article you are looking for: only enter one or two key words related to that article in the relevant entry field.

If you enter a word which is not found in that particular article, even if the other words are present, it will not result in a match. You're better off putting fewer words in the search box and then manually browsing through the resulting list.

For example, say you are looking for a lead-acid battery charger that we published as a constructional project. Your best bet is to deselect the "Circuit Notebook" checkbox (to avoid spurious results) and simply to put "charger" into the Name search field. If you put "battery charger" or "lead-acid battery charger" you may not find it because it might have been named "sla battery charger" or "lead acid battery charger" (no hyphen).

The resulting list will include the year and month of publication, the name of the article, the author(s) and information on any PCBs or kits related to that article. Each entry also includes a link to any items in the SILICON CHIP shop relevant to that project. So this is quite a good way to find items in our shop, as well as articles.

Sometimes you may not know the name of an article but you may remember something specific that is referred to within the article. In this case, you can use the Word Search feature. Open up the Articles menu at the top of the screen and choose the "Word Search" option. You can enter one word, several words, or even a phrase or phrases within quotation marks.

Note that the search function will, in some cases, find

This shows how you can zoom in while viewing an online issue, for example, to get a clearer view of a detailed diagram. On a PC or laptop, this is quite easy — you just point the cursor and spin the mousewheel to zoom in/out.

The results of searching the Name field in the magazine contents database for the term "Micromite". This gives us a list of 25 articles with links to access them directly, as well as listing the associated shop items for each article.

matches within advertisements in more recent issues. This depends on the format in which the advertisement was supplied to us – and whether the advertiser has themselves highlighted products, etc.

(8) LIST ALL ARTICLES

You can list every project, feature article or review ever published in SILICON CHIP

Click on the "Articles by category" entry in the Articles menu to get a list of the (currently) 31 different categories into which SILICON CHIP project articles are organised.

Click on one of the links and you will then be shown a list of all the matching articles, in a format identical to the contents search already described above.

(9) SEARCH INDEXES FOR ELECTRONICS AUSTRALIA AND ELECTRONICS TODAY INTERNATIONAL

We've talked about finding SILICON CHIP articles but there is also the an abbreviated listing of old Electronics Australia and Electronics Today International projects, for which SILICON CHIP owns the copyright.

While we believe that the best way to find SILICON CHIP articles is via the search tools, we also keep an up to date index for each new issue that is published. Simply click on the "Indexes" menu at the top of the website, somewhere near the middle of the screen, and choose either "Silicon Chip Projects Index" or "Silicon Chip Features Index".

(10) READ THE FREQUENTLY ASKED QUESTIONS (AND ANSWERS) FOR SILICON CHIP AND THE WEBSITE

If there's anything you're confused or unsure about, especially regarding the SILICON CHIP website, please read our FAQ, which can be found under the "Help, Contact & FAQ" menu on the right-hand side of the menu bar.

A lot of questions we get via email or over the telephone are already answered in the FAQ! If it doesn't answer your question, please contact us and we may update the FAQ to help others in future.

(11) EASILY FIND ANY SILICON CHIP ONLINE SHOP ITEMS FOR ANY PROJECT

The easiest way to find downloads or shop items associated with a particular project is to use the contents search to find that project, and then click on the resulting Shop link.

However, if you'd prefer to simply view any downloads or purchases available for a given issue, open up the "Shop" menu at top and then select the very last item, "by Year/Month". This will give you a matrix of years and months. The number of items in the shop associated with the issue published in each year/month combination is indicated in parentheses.

Note that the shop includes all article-related downloads, including those which may be available for free. We've done this to keep all the downloads in one place.

You can purchase any or all items by adding them to your trolley as you would do for other websites.

(12) VIEW ALL THE NOTES AND ERRATA FROM ANY YEAR IN ONE PLACE.

We hate mistakes! But at least we tell you about them as soon as we know. When you find when the original article was published (from searching [above], if necessary), select the "Notes & Errata" item in the "Articles" menu and then click on the year your project was published and view the resulting PDF. Scroll down to the particular year and month.

The Notes and Errata, not just for that year but ALL subsequently published for that project will be listed. This way, if you're building a particular project, you can easily find any notes or errata published for it in later issues.

(13) CREATE A NEW NO-OBLIGATION SILICON CHIP ACCOUNT

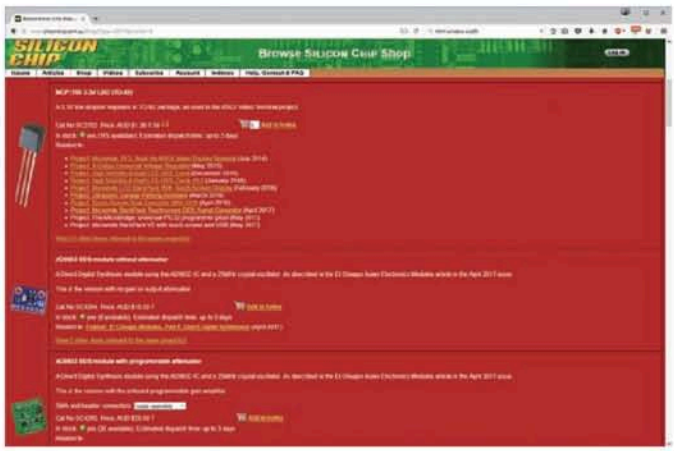
To buy anything from SILICON CHIP, to take out a subscription, etc, you need to set up an account. It won't cost anything until you actually order something from us – and you can use Visa, Mastercard or Paypal. (We use the latest SSL technology data encryption and we don't retain your card details, for your protection)

You're free to set up your own user name and password, and you can change that at any time.

If you provide an e-mail address, we will also use this to send you a subscription renewal reminder.

Incidentally, your information is safe with us: we don't share it with any other organisation (the only exception is when we send your address to our mailing house to send your subscription, etc).

While browsing the magazine covers of all our online issues, simply stop and hover your mouse cursor over one cover to display this handy list of its main contents. You don't need a subscription or even account to do this.



You can browse our online shop in various different ways. In this case, we are looking at the list of all components for sale. This includes some handy pre-built modules that you can use to build our projects, or for your own purposes.

(14) ORGANISE OR RENEW YOUR PRINT/ONLINE/COMBINED SUBSCRIPTION, OR CHECK ITS STATUS

Once you have an account, subscribing to SILICON CHIP is easy. If you want to subscribe to the print edition (via either a print or combined print/online subscription), you should provide your address while signing up. Then all you have to do is click on the "Subscribe" menu at top and follow the prompts

Remember, SILICON CHIP subscribers automatically qualify for a 10% discount on any item from the SILICON CHIP online shop (except, of course, subscriptions!)

(15) ORGANISE A GIFT SUBSCRIPTION

Gift subscriptions are really appreciated by the recipient!

We have an easy, step-by-step process for giving a gift subscription.

You don't need an account to do so, although if you have an account, you will be prompted for the necessary information so that the gift subscription purchase is added to your account. An account for the recipient will automatically be created if it doesn't exist (required to keep track of their subscription and delivery address).

Simply click on the "Gift Subscriptions" menu item in the "Subscribe" menu and then follow the steps to set up the gift subscription, with a message from you to the recipient if you want (eg, "Happy Birthday!").

Incidentally, we don't share your data with any other organizations (obviously, we need to give your address when delivering subscriptions, etc).

(16) VIEWING FROM OVERSEAS?

If you're viewing from overseas, select the "Subscription Rates" option under the "Subscribe" menu to view the cost for subscribing to the print or online versions of SILICON CHIP magazine. Combined subscription rates are also included.

(17) DON'T HAVE AN ACCOUNT YET? USE A TEMPORARY ONLINE TROLLEY

Even without a SILICON CHIP account/subscription, you can add items your're browsing from the SILICON CHIP shop to a temporarily online trolley, to be purchased later (once you have an account). That way you don't have to go through the selection process again!

(18) ACCESS SUBSCRIBER-ONLY OR PAID DOWNLOADS

There are many downloads accessible on the SILICON CHIP website, such as PCB patterns (PDF files), panel art, microcontroller software (source code and/or HEX file) and PC software.

Pretty much all downloads are free if you are a current subscriber. You need to log in to your account to access these free downloads. Some downloads are free regardless. For the rest, if you are not a subscriber, you will need to pay a small amount to download these files and for that you will need an account – see above.

(19) SEND AN ONLINE ENQUIRY

If you click on the "Contact Us" item under the "Help, Contact & FAQ" menu then you can see our address, phone number and e-mail addresses. At the bottom of the page, there is a link to a feedback form where you can send us feedback or a question. We will answer your query as quickly as we can; note though that we are often flat out working on the magazine so we may not get back to you straight away.

(If we think other readers might be interested in your query, it could be published later in "Ask SILICON CHIP").

(20) UPDATE YOUR DETAILS (ADDRESS, PHONE, EMAIL, ETC)

Moved? Changed phone numbers or email addresses? Simply log into your account, go to the "management" page and update as necessary. You can also update your user name or password.

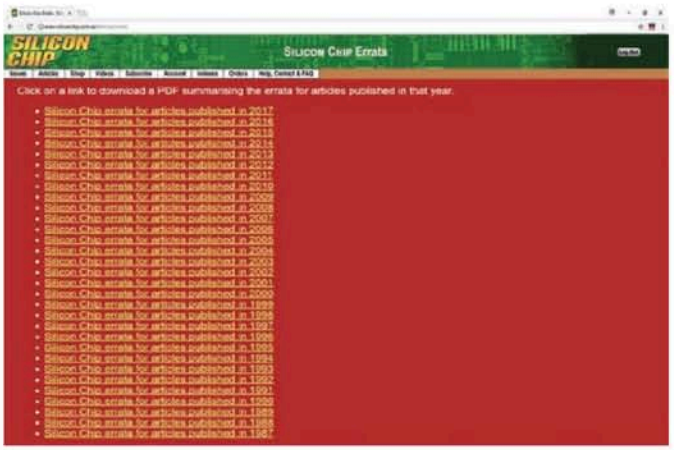
(21) RECOVER A FORGOTTEN PASSWORD

Finally, if you've forgotten your password, don't panic! Hopefully you have provided us with your email address at some point (eg, when you created your account).

Go to the login page (using the "Log In" button in the upper right corner of the main page) and click on the "Forgot Password" link. Enter **either** your login name **or** your email address in the appropriate field and click the "Let Me In!" button.

You will receive an automatically generated email with a link to access your account and change your password. (If the email doesn't arrive within a few minutes, check your spam filter). SC

Another way to browse the shop is via this handy year/month matrix, which lists the number of items that are relevant to the articles in a given issue. Simply click the link to see a list of those items and possibly purchase some,



We collect the Notes and Errata published for every project and put them together based on the year of the article that they refer to. You can then download and view a PDF of these for free on our website, via these links.

High performance Dipole Loudspeaker

Design by Allan Linton-Smith

This loudspeaker, intended for smaller homes and apartments, will really challenge your assumptions about speaker cabinet design. In fact, it has *no* cabinet – and yet it is a wide-range design with a frequency response from 20Hz to 18kHz. To pinch a phrase from the Hitchhiker's Guide to the Galaxy, "*This is, of course, impossible!*" But as Arthur Dent and Ford Prefect found, even the impossible *can* work, albeit (in this case) with the aid of electronic skull-duggery (and perhaps the ultimate answer: 42#)!*

More than a year ago, when this project was first mooted for SILICON CHIP, we were very disparaging, making comments like, "Stupid, impractical idea!", "It could not possibly produce any useful bass!" and some others which cannot be published.

Since then, there have been a number of prototypes produced and the electronic skull-duggery has been refined. Now the results are quite impressive: real, wide-range high quality sound from a loudspeaker system with no cabinet at all, as can be seen in the photos.

But why would anyone want to build a loudspeaker system without a cabinet? Well, why not?

Cabinets can be hard to make and they can have unwanted resonances. It turns out that there are a number of manufacturers around the world who do produce some weird and wonderful dipole loudspeaker systems. But to purchase them you'll need to pay top dollar – we have seen prices from $10,000 to, wait for it, $4,000,000!

Our Dipole Loudspeaker costs *dramatically* less than even the lower figure – and can be built by any electronic enthusiast. You don't even need the wood-working skills a normal speaker cabinet would demand.

In essence, it is just a large timber baffle with three loudspeakers mounted on it: a Celestion horn tweeter and two 10-inch woofers from Altronics.

And the electronic skull-duggery?

Well, this is an active (powered) loudspeaker system, with three power amplifiers and the SILICON CHIP 3-way active crossover featured in the September & October 2017 issues (siliconchip.com.au/Series/318).

The suggested SILICON CHIP power amplifiers are the SC200 (135W into 8Ω) amplifier (described in January, February & March 2017 – siliconchip.com.au/Series/308) and the Tiny Tim 10W per channel stereo amplifier (described in October & December 2013 – siliconchip.com.au/Series/131).

Why such a huge disparity in the power outputs?

We use the Active Crossover to provide lots of bass boost to the woofer, hence the 135W amplifier, while the midrange and horn tweeter can be driven to more than adequate levels with both channels of the Tiny Tim stereo amplifier.

That is a brief description of the concept but let's now discuss the development of the Dipole Loudspeaker.

Development

The designer, Allan Linton-Smith, has been developing the dipole loudspeaker concept over a number of years and had produced some reasonably promising systems but these had always been rejected by SILICON CHIP staff as being way too "thin" in the bass department.

Bass is the real stumbling block, of course. After all with no cabinet, there is nothing to prevent the out-of-phase output from the rear of the woofer from cancelling the output from the front of the woofer. In fact, the overall bass response will be mainly determined by the dimensions of of the baffle board on which the woofer is mounted.

If money is no object (!), you could consider a pair of these Australian-made "Kyron Gaia" dipole speakers. Each one weighs about 200kg and is made to order by Adelaide-based Kyron Audio. They might look pretty cool. . . but be prepared to fork out around a quarter of a million dollars, though! (If that's a bit too much for you, their 3-way "Kyron Kronos" model will set you back just $121,000). Or if you really wanted to go all out, try the Swedish "Transmission Audio Ultra" system. They're reputed to be one of the most expensive speakers in the world – at about $2 million Australian EACH!

Some extremely expensive Dipole Loudspeakers attempt to overcome this problem by using multiple woofers and huge bass drive power but in the end, there are definite limits.

Allan Linton-Smith soon found that bass boosters, such as the Bass Extender from the April 2005 issue (siliconchip.com.au/Article/3034) only made things worse by creating reasonable bass but a very distorted lower mid-range.

Not only was their performance simply not up to scratch but these experimental systems used some very expensive drivers with very impressive specs. These would have been largely unobtainable and/or beyond the budget of average DIY speaker builder.

Then he tried a commercial 3-way active crossover system and that enabled some reasonable progress to be made. This involved using one 10-inch woofer from Altronics (Cat C3026) to cover the low bass frequencies at 100Hz and below.

A second, identical woofer was then used to cover the range from 100Hz to 2kHz. Finally, he used the well-tried Celestion CDX1-1730 and Celestion T5134 horn to cover frequencies from 2kHz upwards.

This is where the first problem arose because there is a huge disparity between the efficiencies of the Celestion tweeter and the Altronics woofer: 110dB/1W@1m compared with 93dB/1W@1m.

Clearly the power amplifier for the tweeter only needs to provide one or two watts. In fact, the tweeter's output needs to be attenuated by about 17dB to match the sensitivity of the Altronics 10-inch driver used as the midrange unit and it can also be driven to reasonable levels from a 10W amplifier such as the Tiny Tim.

But to get bass response to match the levels from the midrange and attenuated tweeter, the second 10-inch Altronics driver needs to be boosted by a whopping 25dB. To do that you need a big amplifier and an active crossover with attenuation slops of 24dB/octave – which the SILICON CHIP Active Crossover is designed to provide.

OK, leaving aside the need for all this electronic augmentation, are there any advantages in a dipole system?

** Above all, DON'T PANIC! Only those who have heard the original BBC radio play "The Hitchhiker's Guide to the Galaxy", by Douglas Adams, or read the book, or even seen the TV series or the movie (all with the same name) will have the slightest idea what these obscure references are all about, especially 42! Hitchhiker's Guide graphic on opposite page courtesy http://hitchhikers.wikia.com/wiki/Earth*

Front and rear views of the final Dipole Loudspeakers. As you can see, the woofer and midrange (actually the same drivers – Altronics/Redback C3026) are mounted to the "baffle" in the conventional way, while the tweeter, a Celestion CDX1-1730 matched to a T5134 horn, is simply screwed to the top of the same sheet of timber. While the woofer and midrange are identical. they handle different frequency ranges, fed to them via the three sets of terminals at the back (one pair feeding the tweeter), all under the control of the SILICON CHIP Active Crossover (September/ October 2017 – siliconchip.com.au/Series/318). The side supports and base were finished with a matte black spray paint.

Note: if you'd prefer not to mar the front panel with screws, you could screw'n'glue the base, side panels and front panel with appropriately placed cleats.

Some people apparently like them because of their subjectively "light, airy and smooth sound". (Does that mean weak bass?)

Another stated advantage is that dipole loudspeakers are "neighbour friendly" because high bass pressures are not created in a listening room and therefore therefore heavy bass signals are not transmitted next door or through the floor – a distinct advantage in flats or apartments where thumping bass can be a major cause of complaint!

So does this mean that no real bass is apparent the listening room?

What you will tend to notice that there are no pronounced standing waves in the room, compared to the sound from a bass-reflex or sealed enclosure.

And don't think that because there is no cabinet, just a straight baffle, that most of the sound will be cancelled. If that were true, there would be virtually no sound produced by a loudspeaker suspended in air with no baffle. Clearly, that is not the case and you can easily verify that for yourself.

But the bass will be weak. So bass frequencies below about 100Hz will need a significant boost in power, as noted above.

Parts List - for EACH speaker

2 250mm (10") woofers (Altronics/Redback C-3026)
1 Tweeter driver (Celestion CDX1-1730)
1 Tweeter horn (Celestion T5134)
1 580x864x18mm baffle, material and finish your choice (we used Kaboodle [Bunnings] blind corner base panels)
1 18mm plywood sheet 610 x 1220mm (or one sheet 2400 x 1200 customwood, etc – does two)
8 12mm x 8g round head screws [for mounting woofers] (or 30mm M4 screws, nuts and washers – see text)
8 30mm x 8g csk head wood screws [for side panels]
14 12mm x 8g stainless csk head wood screws [tweeter/hinges]
2 85mm stainless hinges
3 polarised binding posts (eg Altronics P9257A)
2.5m heavy duty figure-8 cable (with polarity trace/colour)
cable ties, black spray paint etc

Actual performance

As you can see from the frequency response diagrams, this Dipole Loudspeaker system is good from 20Hz to 18kHz ±5dB which is really remarkable when you realise that we are using off-the-shelf drivers! We should state though that it cannot deliver this very good bass response in large rooms – the amount of power needed would simply overload and burn out the woofer.

In fact, we are relying on the Bass Limiter in the SILICON CHIP Active Crossovers to prevent the power amplifier and woofer from being over-driven on loud music passages.

Overall, we were very surprised that a speaker which is virtually "boxless" can produce such impressive bass and which sounded so smooth!

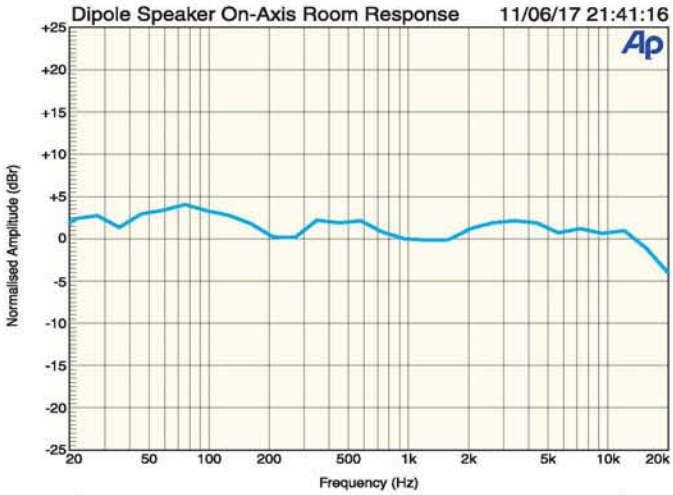
We listened in a furnished room of 5 x 5.4 metres at a distance of about three metres and the bass proved quite substantial. But when we stepped outside the direct listening area, the bass was noticeably reduced.

And of course, there is an advantage when using an active crossover, in that the listener can play around with both the crossover frequencies and the amplitudes of the signals fed to the drivers.

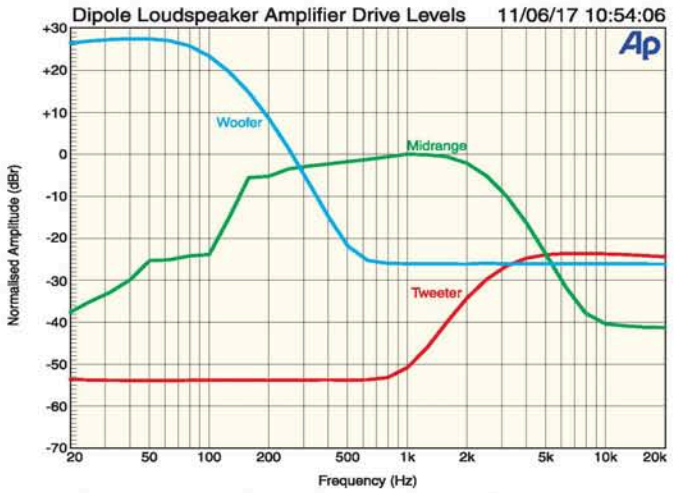
Everyone had a slightly different opinion of how it should sound and this pretty well depended on the program material.

Construction

We'll look at the base and side supports first of all, be-



Overall "room response" of the speaker, measured with a microphone placed directly in front. It's remarkably flat, with just a slight dip above 12kHz; there is no detectable bass roll-off.



Ampltiude of signals being delivered to each driver with a constant amplitude sweep tone fed into the active crossover. Note the large difference between the peak woofer and tweeter power.

cause these are less obvious and can be cut from a variety of timber. We used marine ply – because we had some – but you could use just about any 18mm thick ply, MDF, chipboard, etc. (Don't use anything thinner because it will not support the baffle properly).

If you don't happen to have suitable timber lying around, there is an advantage in buying a single 2400 x 1200 x 18mm sheet of "craftwood" (or whatever brand it's called!) because this gives you much more timber than what you need and we found it to be significantly cheaper than two sheets of 1220 x 620 x 18mm ply ($33.00 vs $37.00 each at Bunnings!) – and you'll have plenty left over for another project.

A cutting diagram is shown for 1220 x 620mm but this would be easily transcribed to the larger sheet. Even though there are only a few pieces to cut, accuracy is important because you need the pieces to fit together well.

If you are a competent woodworker with a saw bench you should have no problem cutting the pieces *but* if you doubt your skills we recommend having it cut professionally (most kitchen cabinet makers will do this for a reasonable cost) and this will make assembly much easier.

If doing it yourself, cut out one speaker at a time to save you correcting any errors twice!

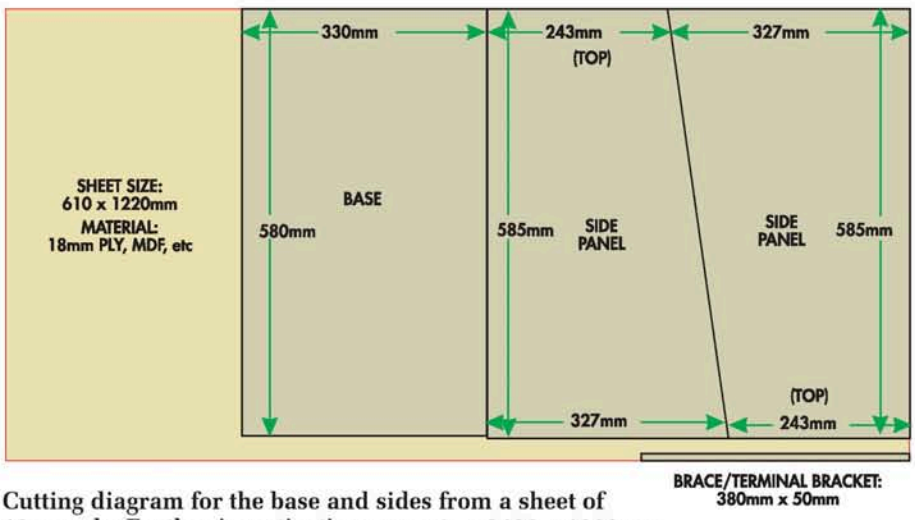
The side supports are screwed to the base using M4 countersunk head (CSK) stainless steel woodscrews. The side supports can be centred on lines 100mm in from each edge, (see drilling diagram overleaf). Four screws are used for each side support with the base countersunk to suit.

A narrow brace (380mm x 50mm) is cut and screwed between the two side panels to support the three stereo binding posts.

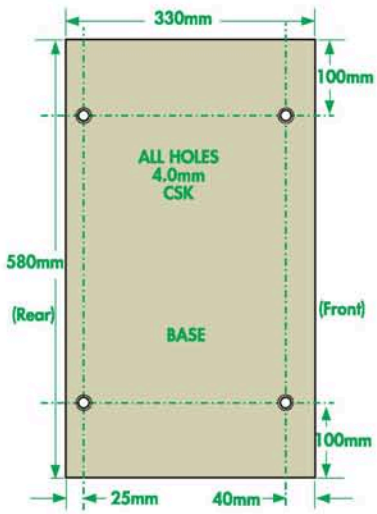
As mentioned elsewhere, we sprayed the side supports, base and brace with matte black spray paint, just for appearance.

The Baffle

Like many of our earlier speakers, we used a 560 x 864 x 18mm "Kaboodle" blind corner panel (from Bunnings) as a baffle. These are available in a variety of colours and finishes and save us having to paint or otherwise prepare and finish the baffle.



Cutting diagram for the base and sides from a sheet of 18mm ply. Further investigation suggests a 2400 x 1200mm sheet of craftwood will cost significantly less and you'll have a lot left over for other projects!



There are only four holes to drill in the base – these accommodate the side panels shown at right.

However, be careful with the surface: they mark very easily if you aren't careful. Leave the protective plastic on the panels until you are finished working with them.

Unlike our earlier speakers, we only need two of these panels because there are no box sides, tops, bottoms or backs to worry about.

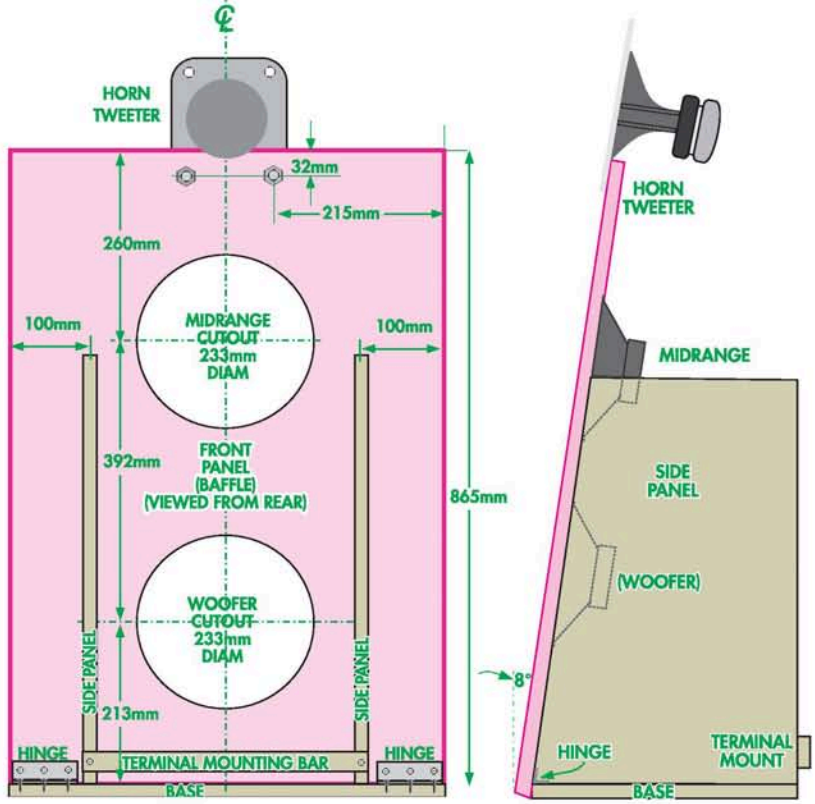
Carefully cut the woofer and midrange holes (233mm) as shown in our baffle diagram – a circle-cutting router makes the neatest cut but if you have to, you could use a jig saw, or drill a series of small holes (say 6mm) inside the required areas and finish off with a rasp, wood file, etc.

Cutting (and drilling) from behind results in less chipping on the front. And remember that old adage: measure twice, cut once!

While you're about it, drill the 4mm holes through the baffle which will hold your side panels in place. The drilling guide (at right)shows their position.

But as an afterthought, we imagine many people would prefer not to have the side panel screws going through the polished wooden baffle.

You could instead use small (say 20 x 20mm) cleats screwed and glued to the panels on the rear side to hold them in place. These would be placed on the inside of the side panels.



If you're going to paint the side panels and base (we sprayed them matte black) now is a good time to do it so that the paint can dry.

Hinges hold it together

Rather than screw the base to the baffle we simply used a pair of 85mm stainless steel hinges to join them. This also allows the correct angle (8°) between the pair when the two side panels are fitted.

You will need an extra pair of hands to hold the baffle against the base when marking the hole positions. Drill all 4mm holes (6 per hinge) to, say, 12mm deep – use the old trick of putting some masking tape around the drill bit (12mm from the pointy end) to ensure you don't go too deep.

Again using an extra pair of hands, align a side panel with the holes you drilled in the base and the baffle and once happy with the location, screw it in position – then repeat for the other side panel.

Placing the speaker drivers in position

If you are happy with the way your dipole speaker "box" looks, you can mount the three speaker drivers.

Start with the two 10-inch drivers. These mount from the front of the baffle. Whether you use 12mm woodscrews or 20mm screws with nuts (ie, right through the baffle) is entirely up to you. You can see the heads of either from the front – so black screwheads will look the best.

In either case, place the driver in its 233mm hole and mark the mounting hole positions (eg, with a felt-tipped pen). Remove the driver (don't be tempted to drill the holes in situ!) and then drill either 3mm pilot holes (for woodscrews) or 4mm mounting holes (for screws and nuts).

Repeat for the other driver before mounting the speakers and (carefully!) placing and tightening the screws (or screws and nuts).

Attach the tweeter driver to its horn, place the assembly against on the top edge of the baffle and mark the screw holes. Again, it's your choice whether you use woodscrews or screws and nuts but as it's only held in with two screws, we'd be more inclined to use the latter – say 4mm x 20mm.

Remove the tweeter/horn before drilling the two mounting holes, then screw the tweeter/horn firmly into position. We used some weather stripping between the horn and baffle to damp any possible vibration; you could also use silicone or a strip of rubber – anything that will break the metal to panel connection.

Wiring it up

Before screwing the terminal mounting bar to the side hinges (where positioning isn't at all critical), drill the holes required to accommodate the three polarised binding posts.

Each requires a pair of 13mm holes at 19mm centres – again, while overall positioning isn't important, it will look much better to have one on the centre line and the other two equidistant apart – say about 75mm each.

Once done, and with the binding posts firmly mounted, screw the bar to the two side panels, as shown above.

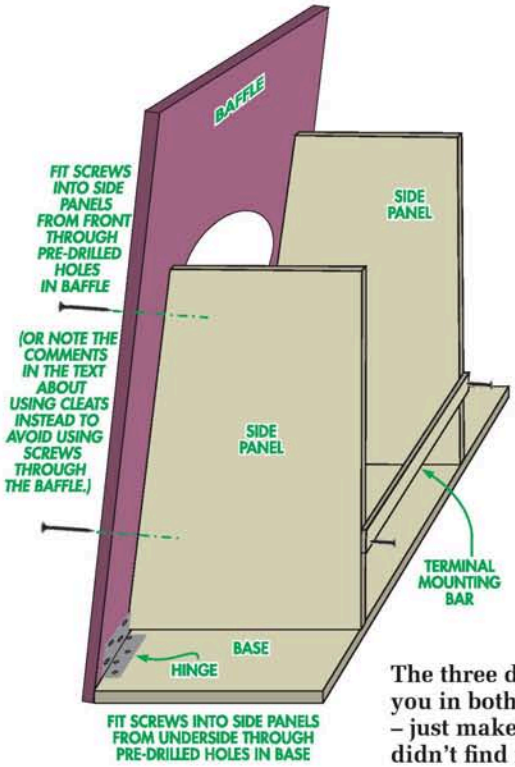
We've specified 2.5m of heavy duty figure-8 cable per assembled speaker. Realistically, only the woofer needs heavy duty cable (remember we're going to pump up to 135W into it!) but there's not too much point in using different cables for the other two drivers.

By the way, we're not specifying "monster cable" or other marketing cons – just polarised, garden-variety figure-8.

You'll only need about 400mm to wire in the woofer, about 600mm for the midrange and about 1000mm for the tweeter. This is being generous, allowing the three cables to be neatly laced together with small cable ties.

When wiring, watch the polarity: the red terminal should always go to the + speaker terminals and black for - (regardless of what colours your wires actually are!).

While any terminal can be wired to any speaker, it makes sense to go in the same order as the drivers: left to the woofer, centre for the midrange and right to the tweeter.



The three diagrams above and opposite, along with the photograph above, should assist you in both drilling and assembling the Dipole Speakers. It's relatively straightforward – just make sure the panel cuts are true and they mate well with each other. While we didn't find it necessary, you could use some wood glue between the base and side panels.

That way, there won't be any errors when you connect your amplifier. (You could also attach some small labels).

Lace together the three cables with some small cable ties – you might also wish to anchor the cable sets to a cabinet side panel but that's up to you.

Sanity check

Just to make sure nothing is amiss, give your finished speaker the once over: make sure the wiring is correct; that there are no rattles or movement etc. Pick the whole thing up (with two people?) and give it a good shake!

If it all checks out OK, repeat the above steps to put together the second speaker.

Checking it out

Even without three amplifiers and the Active Crossover, you can check out that there are no resonances or buzzes etc, by feeding the woofer with a reasonably beefy amplifier (at least 50W or so), playing some good, bassy music (did someone mention Toccata and Fugue in D Minor on a pipe organ?) or even a signal generator feeding it 20-100Hz.

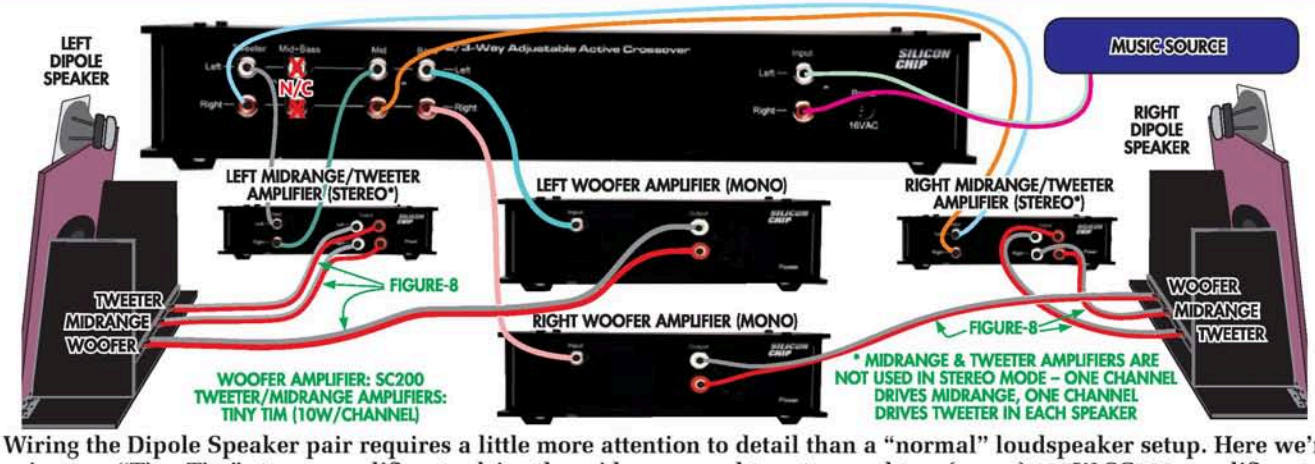
And finally . . .

Final wiring up is simple: connect your music source to the Active Crossover, take the three active crossover outputs (bass, midrange and treble) to your SC200 (bass) and Tiny Tim (tweeter and treble) amplifiers and take their outputs to the appropriate Dipole Speaker terminals, as shown in the connection diagram below.

Some adjustment of the Active Crossover controls to suit your particular tastes may be required – but having total control is what it's all about! As a start, aim for:

Lower crossover: 100Hz; Upper crossover: 2kHz
Woofer gain: 0dB (ie, maximum);
Midrange gain: 25dB below woofer
Tweeter gain: 42dB below woofer

 # What has 42 (the answer to the ultimate question of life, the universe and everything) got to do with anything? Tweeter sensitivity is 42dB below the woofer, of course! SC



Wiring the Dipole Speaker pair requires a little more attention to detail than a "normal" loudspeaker setup. Here we're using two "Tiny Tim" stereo amplifiers to drive the midranges and tweeters and two (mono) 135W SC200 amplifiers to drive the woofers. Note the unusual connections to the Tiny Tims – we're actually using them as two mono amplifiers.

Build your own Super-7 AM RADIO RECEIVER

by John Clarke

All on a single PCB – and no SMDs!

Why, in this day and age, would you want to build an AM Radio Receiver – when you can probably buy one much cheaper? Well, you'll never learn anything by buying off the shelf . . . and you won't have the fun of constructing something that works. Nor will you have the satisfaction of saying to your family and friends: "Look at this! I built it myself!"

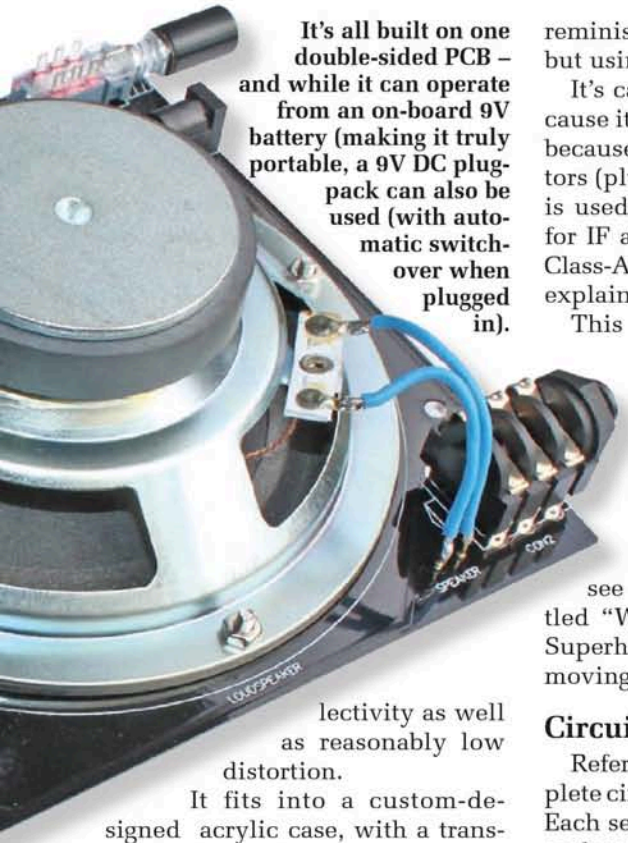
The Super-7 Superhet AM Radio makes a great beginner's project – whether you're 8 or 88!

It is nice and easy to build since all the components mount on a single PCB. They're all standard components (no surface-mount devices to worry about) that are easy to get and they're laid out in a neat manner, making assembly simple and also allowing you to see how it works.

It's powered from a 9V battery or 9V DC plugpack and it automatically switches from battery to the mains supply when it's plugged in.

Audio output is loud and clear from a built-in 100mm (4-inch) diameter loudspeaker but it also has a headphone jack, which automatically disconnects the speaker when in use.

This set has good sensitivity and se-



It's all built on one double-sided PCB – and while it can operate from an on-board 9V battery (making it truly portable, a 9V DC plug-pack can also be used (with automatic switch-over when plugged in).

lectivity as well as reasonably low distortion.

It fits into a custom-designed acrylic case, with a transparent back, so the components are protected but you can still see its workings. It has a large (hand-span) tuning dial showing the current frequency plus many of the available AM radio stations around Australia.

Once built and aligned, you will end up with a fully functioning radio reminiscent of radio sets from the past but using modern technology.

It's called the "Super-7" partly because it is a superheterodyne but also because it uses seven silicon transistors (plus two diodes). One transistor is used for the mixer/oscillator, two for IF amplification and four for the Class-AB push-pull output stage. We'll explain all these terms as we go.

This month we will describe the Super-7 AM Radio circuit, with the assembly and alignment details to follow.

If you know nothing about AM radio technology or the operation of a superheterodyne receiver, please see the accompanying panels titled "What is AM radio" and "The Superhet AM Radio Receiver" before moving on to the circuit description.

Circuit description

Refer to Fig.1 which shows the complete circuit of our Super-7 AM Radio. Each section of the circuit is labelled so that you can see how it relates to the block diagram in the panel on page 50 which explains how a superhet works.

The circuit does not have an RF amplifier stage so the antenna signal is coupled directly to the mixer stage.

The antenna coil (T1) is wound on a small ferrite rod. The high permeability of the ferrite material allows a compact antenna of this type to pick up signals that would otherwise require a fairly long standard antenna.

The primary coil is tuned in a parallel resonant circuit by one section of the plastic dielectric tuning gang, VC1. Trimmer capacitor VC2 is in parallel with VC1 and is set during alignment of the AM radio so that stations appear at the correct location on the dial.

A secondary coil on the ferrite rod couples the tuned signal into the base of transistor Q1, via a 22nF capacitor, and Q1 functions as a self-oscillating mixer.

It oscillates at a frequency set by the parallel resonant circuitry connected to its emitter, ie, the primary of T2 plus VC3 and VC4.

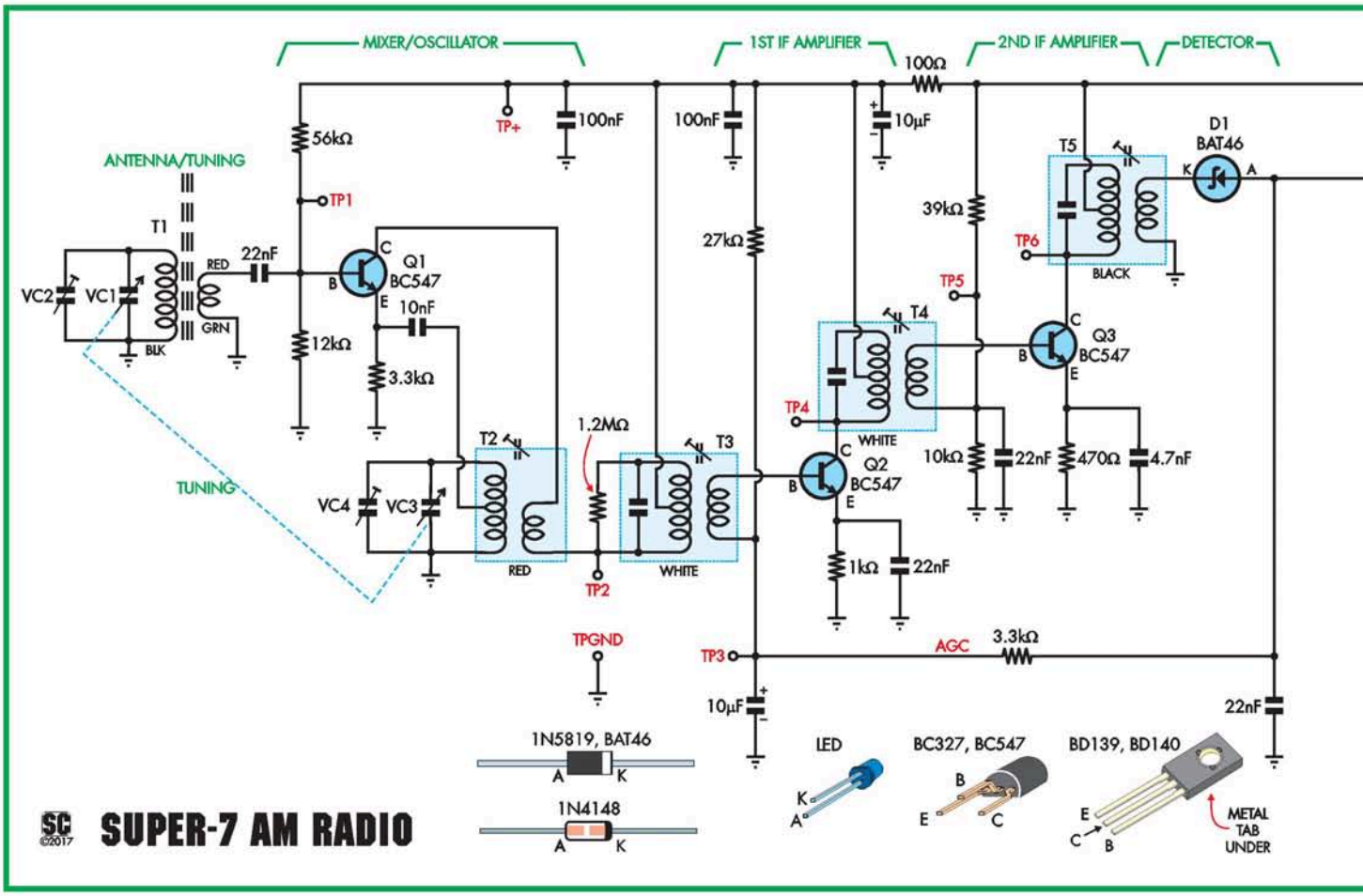
This oscillator is tuned by the second section of the tuning gang, VC3. Again, VC4 is a trimmer, connecting in parallel with VC3, and is set during the alignment process so that the oscillator frequency tracks the tuned frequency with the correct offset of 455kHz.

The oscillator transformer, T2, has its secondary winding connected in series with the collector of Q1. This provides feedback to Q1 to sustain oscillation.

The output signal of the mixer/oscillator appears at the bottom end of this secondary and is fed to the primary of transformer T3.

This is adjusted (via its integral tuning slug) to be resonant at the intermediate frequency of 455kHz.

Here is the "front" side of the Super-7 AM Radio Receiver – the side which normally faces you. It sports a quite large speaker (which gives it really good tone!), the volume control (the knob in the lower right), power LED and, not shown here, the tuning dial, which attaches to the shaft in the centre of the circle at right at right. Most major AM stations are shown on the dial and even some minor stations, along with frequency around the circumference.



So it selects the intermediate (difference) frequency and filters out most of the original frequency as well as the oscillator signal and sum products. Its primary also forms the collector load for transistor Q1 and a 1.2MΩ parallel resistor sets its Q, determining its bandwidth.

The output IF signal from the secondary is applied to the base of the first IF amplifier transistor, Q2. A 27kΩ resistor from the positive rail provides its base with a DC bias current. Its 1kΩ emitter resistor is bypassed with a 22nF capacitor to maximise the gain.

Transformer coupling

These transformer coupled stages may seem odd to readers who are used to seeing circuits in which transistor stages are directly coupled, ie, without capacitors or transformers.

There are several reasons for using transformers.

The first is that, as stated above, the IF transformers filter out unwanted frequencies so that the transistors don't waste power amplifying unwanted signals, which could potentially even cause them to saturate.

They also improve selectivity, by limiting the bandwidth of the signal being amplified.

Second, the IF transformers provide the right degree of impedance matching between the relatively high impedance of the collector circuits of the transistors and the relatively low impedance base circuit of the following transistor. This optimises the available gain.

Note that in each case, the collector current of the transistor passes through only a portion of the transformer primary and this is part of the intended matching process.

Note also the circuitous path followed by the DC collector current for the mixer transistor Q1. The current passes through part of the primary of the 1st IF transformer (T3) and then via the secondary of oscillator transformer T2), before arriving at the collector of Q1.

Now turn your attention to the second IF transformer, T4. Its primary is the collector load for Q2 while the output from its secondary is fed to the base of Q3.

Besides a few details of the biasing of Q3, this amplification stage is essentially identical to Q2 and it provides more gain for the signal before it's fed to the detector.

Detector diode

This role is performed by diode D1 but while the detector looks simple, there is more to it than first appears. The detector diode is driven by the secondary winding of the third IF transformer, T5.

This diode performs two tasks. Firstly, it detects or demodulates the amplitude modulated IF signal to produce an audio signal and secondly, it produces the AGC voltage which is used to control the gain of the 1st IF amplifier, Q2.

D1 is a Schottky diode, selected for its low forward voltage drop of about 0.3V. Germanium diodes, with a 0.2V forward voltage drop, have traditionally been used as detectors but they are starting to be hard to find.

D1 rectifies the negative-going portion of the IF signal, resulting in a negative output voltage. Its anode is connected to a 22nF capacitor and provides the first stage of RF filtering,

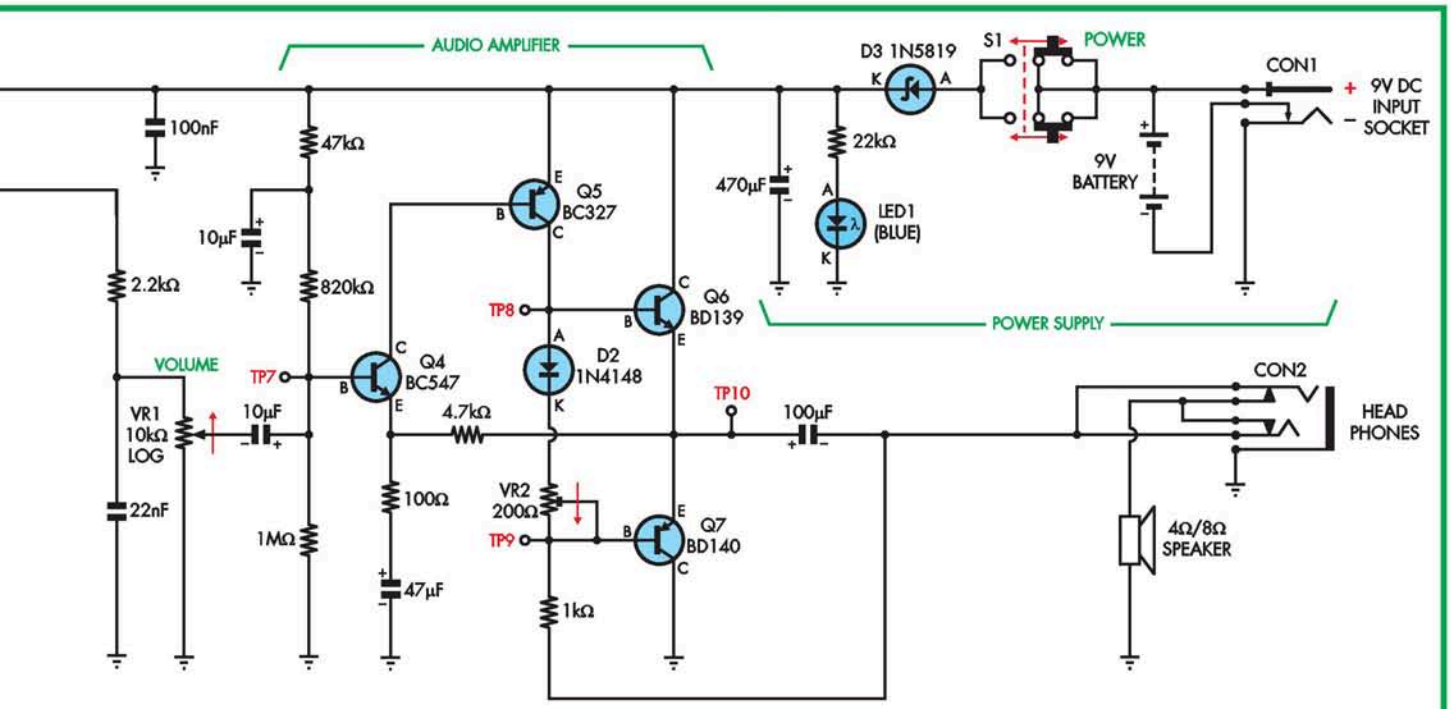


Fig.1 : the Super-7 receiver uses seven commonly available transistors. The incoming RF signal is picked up by the ferrite rod antenna and fed to Q1 which functions as a self-oscillating mixer. The "difference" signal (between the oscillator and tuned input signal) is then coupled via T2 to the two IF amplifier stages and onto detector diode D1, to recover the audio signal and generate AGC, which is fed back to Q2. The audio signal is then fed, via volume control VR1, to the amplifier stage comprising Q4-Q7.

and then via a 2.2kΩ resistor to a second 22nF capacitor for more filtering of the final audio signal before being applied to the 10kΩ volume control potentiometer, VR1.

The demodulated signal is also coupled via a 3.3kΩ resistor to a 10µF filter capacitor, which forms a low-pass filter with a -3dB point of 5Hz. Thus, the audio portion of the signal is eliminated before being fed back to the base of Q2 via T3's secondary.

The AGC works as follows: if a large signal is being picked up, diode D1 will produce a larger than normal negative DC voltage and this will tend to throttle back the base bias voltage of Q2.

So Q2 will conduct less current and its gain will consequently be reduced. The stronger the signal, the greater the gain reduction and hence the chance of signal overload is greatly reduced.

Note the rather complicated bias network for the base of Q2. Current passes first via the 27kΩ resistor, the 3.3kΩ and 2.2kΩ resistors associated with diode D1, and then via the 10kΩ volume control pot VR1. The base current flows from the junction of the 27kΩ and 3.3kΩ resistors via the secondary of the 1st IF transformer (T3).

Another thing to consider is that the current flowing through the 27kΩ and 3.3kΩ resistors will tend to forward-bias D1 slightly, offsetting its forward voltage and thus slightly increasing its sensitivity and reducing audio distortion.

Having the bias current flow through the volume control pot is not ideal because pots with DC flowing through them will cause a little noise during rotation.

Potentiometers become even noisier if DC current flows via the wiper but this does not happen in this circuit since we use a 10µF coupling capacitor.

Audio amplifier

The audio signal from the volume control is fed to a 4-transistor amplifier consisting of Q4, Q5, Q6 & Q7. This amplifier is directly coupled throughout, apart from the output capacitor which we'll come to in a moment. Q4 is connected as a common-emitter stage with all its collector current becoming the base current of the following PNP transistor, Q5.

Q5 also forms a common-emitter stage and provides most of the voltage gain of the audio amplifier. Its collector current flows partly into the bases of the push-pull output transistors, Q6 and Q7, while the rest goes through the 1kΩ resistor and loudspeaker to ground.

Output transistors Q6 and Q7 are connected as complementary emitter followers in class-AB mode.

To explain class-AB, this is a variant of class-B operation. In class B, Q6 conducts for one half of the signal waveform, then turns off, and Q7 takes over for the second half of the signal waveform.

This switching process inevitably causes crossover distortion which can make the sound quality quite unpleasant.

Class-AB fixes this by making sure the transistors never fully turn off.

So the two output transistors are slightly biased into forward conduction by the voltage developed across diode D2 and trimpot VR2. VR2 provides quiescent current adjustment to minimise (but not completely eliminate) crossover distortion.

The Superhet AM Radio Receiver

The basic operation of a superheterodyne AM radio receiver (usually abbreviated to "superhet") is shown in the block diagram below.

There are many variations on this theme but all rely on the principle of heterodyning, or mixing, different frequencies. Heterodyning is applied in order to provide high gain, without instablility.

The antenna is tuned by a variable capacitor in a parallel resonant circuit.This variable capacitor is one section of a "ganged" capacitor (ie, two sections on the one shaft or control). The other section of the ganged capacitor varies the local oscillator which we'll come to in a moment.

The parallel resonant circuit is tuned by the variable capacitor so that the wanted signal is selected while signals at other frequencies are rejected. The signal from the antenna is then fed to the mixer and this is where the "superheterodyne" process takes place,

The word "heterodyne" refers to the "beating" effect generated by mixing two signals of different frequencies. "Hetero" is derived from the Greek word for "other" while "dyne" is derived from the French word for power. "Super" here refers to the fact that the second frequency is higher than the frequency of interest.

In the Mixer stage, the Local Oscillator signal is mixed with that from the antenna. The result is a signal with components at four different frequencies: the two original frequencies (ie, the carrier and local oscillator), plus the sum and difference frequencies.

Assuming the carrier and local oscillator frequencies are close together, the sum will be at around twice the tuned frequency while the difference will be at a much lower frequency.

This resulting signal is passed to an amplifier stage or stages tuned to the difference frequency, which results in the rejection of signals at the three other frequencies. The difference frequency is referred to as the Intermediate Frequency or IF.

In most radios of this type, the Intermediate Frequency is 455kHz or 450kHz. The first superhets had an intermediate frequency of 50kHz which gave very sharp selectivity but poor audio response, because of the necessarily low bandwidth of the IF filters. Later, the standard IF was 175kHz and later still this was standardised at 455kHz.

The output of the IF stage is then applied to the detector, which in transistor radios is usually a germanium diode, selected because of its low forward voltage drop. (We've used a "schottky" diode in the Super-7 circuit for the same reason – ie, low voltage drop).

The diode rectifies the IF signal which is then filtered to remove RF carrier, leaving the audio signal. This is then fed to the audio amplifier, which drives a loudspeaker.

Automatic gain control

Apart from demodulating the IF signal, the detector is also used to produce the AGC voltage. AGC was regarded as a wonderful innovation when it was introduced as it eliminated the need to adjust the set's gain each time you tuned into a new station. Gain adjustment is necessary to stop the IF stages from overloading on strong signals while still providing sufficient gain for very weak signals (eg, from distant or low-powered stations).

To derive the AGC voltage, the raw DC output from the detector is heavily filtered to remove the audio signal, producing a DC voltage that is proportional to the amplitude of the IF signal.

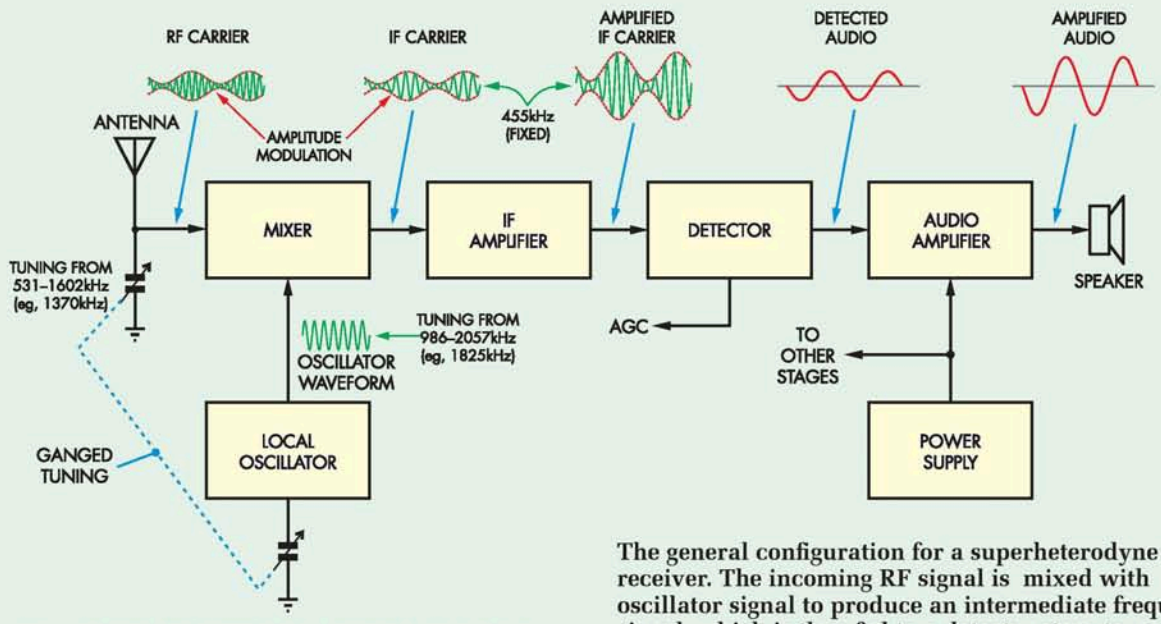
This is then used to control the gain of the IF stages and sometimes also the RF stage, so that the signal is held to a more or less constant level, ie, using negative feedback.

So why "superheterodyne", rather than "subheterodyne", ie, with the local oscillator below the station frequency? After all, this would produce the same difference frequency. This was tried but it results in a lower sum frequency component which can be within the broadcast band, resulting in "ghost stations" (or "image frequencies") on the dial, at higher frequencies than the actual station. This is pretty much totally eliminated in a superhet.

Local oscillator

The local oscillator frequency always tracks the tuned frequency of the RF amplifier. So for an IF of 455kHz, if the radio is tuned to 1370kHz, the local oscillator will be set to 1825kHz (1370 + 455). Similarly, if the radio is tuned to 702kHz, the local oscillator will be at 1157kHz (702 + 455).

All this happens automatically by virtue of



SC ©2017 **SUPERHETERODYNE RADIO**

The general configuration for a superheterodyne radio receiver. The incoming RF signal is mixed with a local oscillator signal to produce an intermediate frequency (IF) signal, which is then fed to a detector stage to recover the original audio signal.

the 2-section capacitor tuning gang – one section is for tuning the antenna and the other for the local oscillator. These variable capacitors track each other over the adjustment range. Various tricks are used to create the necessary frequency offset while maintaining good tracking.

Variations on a theme

While we have just described the broad concept of the superhet, there are many variations on this theme. For example, many superhet circuits have a tuned RF Amplifier stage and some do not have a separate local oscillator. Instead, the local oscillator is combined with the mixer stage in what is known as a self-oscillating mixer or mixer/oscillator (as in the Super-7 circuit).

Others may have two or three IF stages and some may have a separate detector to produce the AGC voltage.

Another important variant is the double conversion configuration used in some high-performance communications receivers. This combines two superhet stages to shift the signal frequency in two "steps" and is usually used for receiving shortwave signals, as these are at much higher frequencies (up to 30MHz) than broadcast AM stations.

The Super-7 circuit is a "single conversion" superhet, meaning that it performs just one conversion from the incoming RF frequency to the intermediate frequency.

Other variations which are common include "permeability tuned" superhets and today's frequency synthesised receivers with digital readouts and microprocessor control.

Permeability tuning was common in car radios, where tuning was done by varying inductance rather than capacitance. One advantage of permeability tuning, especially useful in cars, is reduced susceptibility to vibration.

Regardless of all the variations, you will find that all superhets have the same operating mode and same circuit functions as described by the block diagram above.

By the way, Edwin Armstrong, who invented the AM superhet receiver was the same person who later developed the principles of FM transmission and reception.

One further note before we leave the origins of the superhet: apparently, radio (or "wireless") circuits working along the same principle were used in British submarines during the First World War.

Negative feedback from the output of the amplifier is provided by the 4.7kΩ resistor to the emitter of Q4. The AC voltage gain of the amplifier is set to about 47 by the 100Ω resistor from the emitter of Q4, while the series 47µF capacitor sets the bass roll off of the amplifier.

Amplifier output with no signal sits at about half supply, ie, around 4.5V. This DC offset is removed by using a 470µF coupling capacitor between the amplifier output and the loudspeaker.

The capacitor allows the AC signal to pass to the loudspeaker but blocks the DC voltage. The DC needs to be blocked to prevent the loudspeaker cone being forced away from its normal resting position and increasing distortion.

By now, you've probably realised that this design aims to achieve good performance without using too many components, similar in concept to a portable AM radio.

For example, the output stage component count has been minimised by connecting the 1kΩ resistor to 0V via the speaker coil.

The same DC bias conditions could have been obtained in the output stage by simply connecting the 1kΩresistor directly to the 0V line but there is a good reason for doing it the way we have.

Bootstrapping

By connecting the 1kΩ resistor via the speaker, we take advantage of the fact that the output stage transistors are emitter followers. In this mode, these transistors have a voltage gain just slightly less than one.

This means that the AC signal voltage at the emitters of Q6 and Q7 (and hence across the speaker) is only slightly less than the signal voltage at the bases of these two transistors. Because of this, the AC voltage applied across the 1kΩ resistor is very small and so little AC current flows.

Hence, transistor Q5 "sees" a much higher collector load than the nominal 1kΩ. This means it is able to provide more drive to the output stage and higher overall voltage gain.

This technique is known as "bootstrapping" and is commonly used in audio amplifiers. However, while this is an effective method which improves the overall performance, it does have one drawback.

If the loudspeaker or headphone is not in circuit, no current can flow through the 1kΩ resistor. If this happens, the output stage is not biased on and the whole amplifier draws no current at all.

This may not seem important because the speaker will normally always be connected. But if you try to monitor the amplifier without the speaker connected or plug in a bare jack socket into CON2, no current will flow through it and the amplifier won't work. So don't be trapped!

One other little circuit trick needs to be noted before we finish this article and this involves the 470µF capacitor that connects across the 9V supply.

This relatively large capacitor may seem unnecessary. But since the circuit can be powered from a 9V battery as well as a DC plugpack, it is a requirement.

That's because as the battery ages, its internal impedance rises and so it is less able to deliver the relatively high current pulses demanded by the amplifier and the result is more distortion from the amplifier.

By placing the 470µF capacitor across the 9V supply, we effectively reduce the AC impedance of the battery and thus enable it to deliver those higher current pulses. The result is better sound quality.

Note that the speaker signal goes via the integral switch in headphone socket CON2, so that if headphones/an earphone is plugged in, the speaker is automatically disconnected.

Note also that the tip and ring connections are wired in parallel, so you will get audio from both sides of stereo headphones/earbuds, even though the AM radio output is mono.

Finally, indicator LED1 shows when the circuit is switched on, via power switch S1 and reverse battery protection diode D3.

D3, is another schottky diode, which means that its very low forward voltage will result in minimum loss from the battery, while still protecting against accidental polarity reversal.

While you can't permanently fit a 9V battery in the holder the wrong way around, you can certainly make accidental contact the wrong way around.

In the next article, we will show you how to assemble your Super-7 AM Radio, including its custom-made case and hand-span dial.

We will also describe the alignment procedure.

What is "AM" radio?

When radio stations first began broadcasting in Australia (and for many decades after), they all used the amplitude modulation (AM) system, predominantly using the "broadcast band" which covers 531kHz to 1.602MHz.

The other transmitting system, FM, or frequency modulation only commenced in Australia in the 1970s and uses a higher frequency band, from roughly 88 to 108MHz. And more recently, the digital system, DAB+, transmitting on a range of frequencies around 200MHz, has started mainly in capital cities.

Apart from the difference in frequencies, trying to listen to AM with an FM receiver (or vice versa) will not be successful. The same applies to DAB+ on any other receiver.

AM transmission

AM is relatively simple: it involves transmitting a signal with a fixed frequency (known as the radio frequency [RF] carrier) but its amplitude (power) is modulated, or varied, by the voltage level of an audio signal such as from a microphone or music being played.

The receiver is tuned to the carrier frequency and once it picks it up, it's "demodulated" to produce a voltage that's proportional to the signal amplitude. The resulting signal is then amplified and fed to the radio's loudspeaker.

The "state of the art" analog approach for receiving an AM signal is superheterodyne (or "superhet") principle, invented by Edwin Armstrong in 1918. The first commercial AM superheterodyne radios were put on the market by Radio Corporation of America (RCA) in 1924. Later, RCA licensed other manufacturers so that the design was used worldwide.

Prior to the superheterodyne, radios were either crystal sets or used the tuned radio frequency (TRF) principle, of which there are a number of variations. In a TRF receiver, all amplification up to the detector (demodulator) takes place at the frequency of the incoming signal.

The superheterodyne radio brought with it two major advantages over previous circuits. The first was greatly increased gain. This was a big boost compared to TRF tuners which were strictly limited as far as maximum gain was concerned when using valves (or "vacuum tubes"). Any attempt to increase the gain over this limit would cause the circuit to oscillate, resulting in a loud squeal.

Second, the selectivity of the superheterodyne was a big improvement over previous circuits and this meant that weak stations could be separated out from strong stations that would otherwise tend to blitz half or more of the tuning dial.

Finally, the superheterodyne receiver brought with it the possibility of automatic volume control (AVC), also known as automatic gain control (AGC), although this did not become a feature until around 1930. AGC did away with the need for manual gain controls and meant that all stations came in with roughly the same loudness, in spite of the fact that some stations may be very strong and some very weak.

Since the advent of the superhet, there have been relatively few changes to the basic circuit configuration until the advent of software-defined radios (SDRs), although the components used have changed radically over time. Originally, valves ruled but now transistors are used or even a single integrated circuit with just a few external components.

So if you decide to build this AM superhet receiver, you will be building a circuit configuration which has been around for over 90 years but one which is still just as relevant today.

Parts list – Super-7 AM Radio Receiver

1 double-sided PCB coded 06111171, 313 x 142.5mm
1 set of laser-cut acrylic case and dial pieces (Silicon Chip Online Shop Cat SC4464)
1 AM radio coil pack (Jaycar LF-1050) (T2-T5)
1 mini tuning gang capacitor (Jaycar RV-5728) (VC1-VC4)
1 ferrite rod with coil (Jaycar LF-1020) (T1)
1 100mm (4-inch) 4- or 8-ohm loudspeaker
1 DPDT push-on/push-off switch (Altronics S 1510) (S1)
1 round knob for switch S1 (Altronics H 6651)
1 16mm 10kΩ logarithmic taper potentiometer with 6.35mm D-shaft (VR1)
1 knob to suit VR1
1 2.1 or 2.5mm inner diameter DC socket (Altronics P 0621A, P 0620, Jaycar PS-0519, PS-0520) (CON1)
1 6.35mm stereo switched jack socket (Altronics P 0073, Jaycar PS-0190) (CON2)
1 9V DC 250mA (or higher current) plugpack and/or 9V battery
1 9V PCB battery holder (Altronics S 5048, Jaycar PH-9235)
12 PC stakes
8 M3 tapped 25mm spacers
8 M3 flat washers
8 M3 x 10mm machine screws
4 M3 x 15mm Nylon or Polycarbonate machine screws
4 100mm cable ties
3 No.4 x 6mm self-tapping screws
4 M3 x 15mm machine screws and nuts (for mounting speaker)
1 150mm length of medium-duty hookup wire

Semiconductors
4 BC547 NPN transistors (Q1-Q4)
1 BC327 PNP transistor (Q5)
1 BD139 NPN transistor (Q6)
1 BD140 PNP transistor (Q7)
1 BAT46 schottky diode (D1)
1 1N4148 diode (D2)
1 1N5819 schottky diode (D3)
1 3mm high brightness blue LED (LED1)

Capacitors
2 470µF 16V PC electrolytic
1 47µF 16V PC electrolytic
4 10µF 16V PC electrolytic
3 100nF ceramic
1 47nF MKT polyester
4 22nF MKT polyester
1 10nF MKT polyester
1 4.7nF MKT polyester

Resistors (0.25W, 1% [*^5% carbon OK*])

1 1.2MΩ^	1 1MΩ	1 820kΩ	1 56kΩ
1 47kΩ	1 39kΩ	1 27kΩ	1 22kΩ
1 12kΩ	1 10kΩ	1 4.7kΩ	2 3.3kΩ
1 2.2kΩ	2 1kΩ	1 470Ω	2 100Ω

1 200Ω miniature horizontal trimpot (VR2)

SC

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Jaycar Electronics

$99.95

48W TEMPERATURE CONTROLLED SOLDERING STATION

TS-1564

Features accurate analogue temperature adjustment, ceramic element and a lightweight pencil for fatigue-free soldering.

- Temperature range: 150 - 450°C
- Lead-free rated
- 150(L) x 115(W) x 92(H)mm

ALSO AVAILABLE:

SPARE SOLDERING PENCIL TS-1565 **$39.95**
0.5MM CONICAL TIP TS-1566 **$9.95**
2.0MM CONICAL TIP TS-1567 **$9.95**

$299

SAVE $60

SERIOUS ABOUT SOLDERING?

TS-1584 **RRP $359**

An outstanding, fast, accurate 50W ESD safe soldering station from Thermaltronics uses the proven Curie Point technology to bring the tip up to operating temp using fast RF induction. It works with leaded and unleaded solder. Mains powered. 0.5mm chisel tip included. 155(H) x 110(W) x 92(D)mm.

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SPARE TIPS WITH HEATING ELEMENT FROM $29.95

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LEARN ABOUT... ...CURIE POINT TECH

Jaycar has a select range of advanced soldering stations that use Curie Point Heating technology. High control of tip temperature, cannot overshoot the Curie point temperature during tip temperature recovery, means a better soldering experience, professional outcome and less risk of damage to components or boards.

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300W HOT AIR REWORK STATION WITH LED DISPLAY TS-1645 WAS $149

By using hot air rather than a soldering iron, you get a more uniform heat transfer and melt all solder pads at once making SMD chip removal safe and effective.

- 100-500°C temperature range
- Pushbutton / digital display
- 160(L) x 113(W) x 123(D)mm

$159

PORTASOL PRO PIEZO GAS SOLDERING KIT TS-1328

Features 120 minutes run time, 10 seconds fill, and 30 seconds heat up. Maximum 580°C tip temperature (max 1300°C for built-in blow torch). Includes quality storage case.

See website for full contents.

ALSO AVAILABLE:

BUTANE GAS NA-1020 **$4.95**

$19.95

25W SOLDERING IRON WITH LED TS-1468

Illuminate the area so you have a better solder joint. Fast heat up, good temperature constancy, and replaceable tips. Mains powered.

- Integrated switch
- 1m cable length
- 215(H) x 35(Dia.)mm

$39.95

PIEZO IGNITION MICRO TORCH

TS-1660

Ideal for brazing, silver soldering, jewellery work, heat shrinking, plumbing and general hobby work. Includes bonus stand.

- High temperature 1300°C flame
- Adjustable flame
- 155(H) x 35(Dia)mm tank

ALSO AVAILABLE:

BUTANE GAS NA-1020 **$4.95**

$17.95

SOLDERING IRON TIP CLEANER

TS-1510

Eliminates the temperature variation associated with the wet sponge.

- Supplied with spare insert

$16.95

METAL DESOLDER TOOL

TH-1862

Made of lightweight metal and has strong suction.

- Automatically cleans itself with each action
- 195mm long

$15.95 ea

200G DURATECH SOLDER

60% Tin / 40% Lead. Resin cored. 2 sizes available.

0.71MM NS-3005
1.00MM NS-3010

$5.95 ea

GOOT DESOLDER BRAID

High quality, Japan made.

- 1500mm long

1.5MM WIDE NS-3026
2.0MM WIDE NS-3027
3.0MM WIDE NS-3028

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TEMP & ENVIRONMENTAL MODULES FOR YOUR ARDUINO®

$37.95

ULTRAVIOLET SENSOR MODULE XC-4518

Can be used to measure UV exposure from the sun, or even check that your UV steriliser or EPROM eraser are working correctly.

- Response wavelength 200-370nm

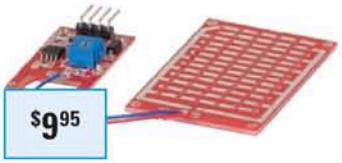
$19.95

DATA LOGGING SHIELD XC-4536

Save your data to an SD Card (not included), and use the inbuilt battery backed clock module to timestamp your readings.

RAIN SENSOR MODULE XC-4603

This sensor will detect contact from any conductive object, not just rain, so it could be used for as a large touch sensor panel as well as letting you know when it's raining.



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$9.95

TEMPERATURE AND HUMIDITY SENSOR MODULE XC-4520

Fully digital operated so no analogue-to-digital calibration is required.

- Temperature Range: 0 °C - 50 °C +/- 2 °C
- Humidity Range: 20 – 80% +/- 5%
- Sample Rate: 1Hz

$9.95

ALCOHOL SENSOR MODULE XC-4540

Detect alcohol, smoke and other volatile substances. Check for gas leaks, use it as a smoke detector, or even track how your home brew is going. Adjustable sensitivity.

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30A CURRENT SENSOR MODULE XC-4610

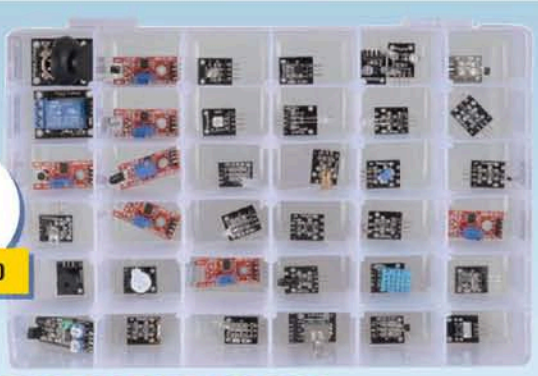
Outputs a voltage proportional to current passing through the sense pins on the module. Uses ACS712 hall effect sensor.

- Output ratio is 66mV/A
- Compact board only 31mm x 13mm

$5.95

PHOTOSENSITIVE LDR SENSOR MODULE XC-4446

Measures light levels. Connect it straight into your Arduino® board to build a night/day sensor, a sun tracker or combine it with our laser module XC-4490 to make a laser trip wire. Includes breakout cable.



$99

SAVE $30

DELUXE MODULES PACKAGE XC-4288 WAS $129

Get more savings by purchasing this 37 modules-in-1 pack. Includes commonly used sensors and modules for Duinotech and Arduino®: joystick, magnetic, temperature, IR, LED and more. *See website for details.*

$5.95

TEMPERATURE SENSOR MODULE XC-4494

Outputs an analogue voltage that varies directly with temperature. Connect it straight to one of your duinotech analogue inputs. Max 100°C.

- 21cm breakout cable included

$4.95

SOIL MOISTURE SENSOR MODULE XC-4604

Automate your garden with Arduino® and use this module to detect when your plants need watering.

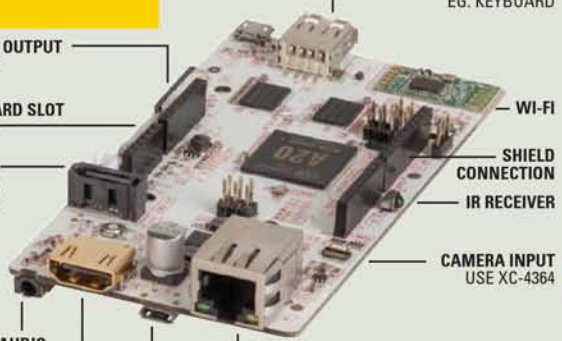
- Analogue output
- Current less than 20mA

LEARN MORE ABOUT PCDUINO, VISIT: jaycar.com.au/pcduino

PCDUINO V3.0 WITH WI-FI XC-4350

- Built in Wi-Fi capability
- Supported digital audio via I2C
- 121(L) x 65(W) x 15(H)mm

$89.95



7" LCD TOUCH SCREEN MONITOR XC-4356

1024 x 600 resolution. LVDS screen with driver board. 167(L) x 107(W) x 10(D)mm

$89.95

VOLTAGE CONVERTER MODULE XC-4362

Marries 5V Arduino® shields with the 3.3V pcDuino to stop damage caused by connecting a 5V shield to pcDuino. 70(L) x 50(W) x 4(D)mm

$24.95

PCDUINO 5MP CAMERA XC-4364

Connects directly to pcDuino V3.0, and captures an active array of video and images up to 2592 x 1944 resolution.

$19.95

BLACK ENCLOSURE XC-4354

House your pcDuino in this enclosure for a safe and presentable appearance.

- Suits XC-4350

$19.95

SATA CABLE XC-4366

Connects your pcDuino V3.0 to a hard drive or SSD.

- 150mm long (approx.)

$4.95

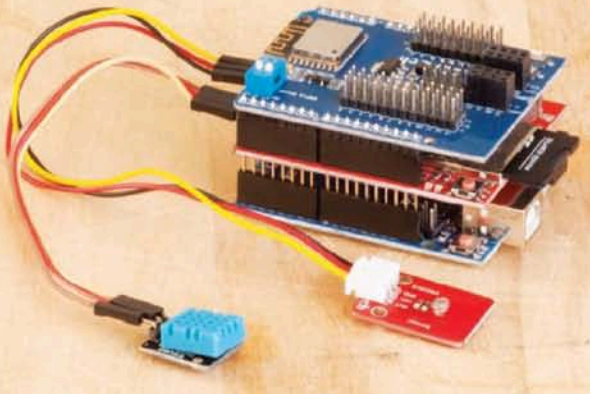
PROJECT OF THE MONTH

WI-FI ENVIRONMENTAL DATALOGGER

If you're interested in measuring what's going on in your environment, this project is a handy thing to build. It has sensors to measure temperature, humidity and light levels, but it can be made to log just about anything an Arduino can sense. What's great on this project is you can download the data via Wi-Fi, and view it in a spreadsheet program. *Some soldering required!*

VALUED AT $122.50

SEE STEP-BY-STEP INSTRUCTIONS AT:
jaycar.com.au/wifi-datalogger



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XC-4410

XC-4614

XC-4536

XC-4446

XC-4520

WC-6026

XC-4983

HM-3211

WHAT YOU NEED:

UNO MAIN BOARD	XC-4410	**$29.95**
WI-FI SHIELD	XC-4614	**$34.95**
DATALOGGING SHIELD	XC-4536	**$19.95**
PHOTOSENSITIVE LDR MODULE	XC-4446	**$5.95**
TEMPERATURE & HUMIDITY SENSOR MODULE	XC-4520	**$9.95**
SOCKET-SOCKET JUMPER LEADS	WC-6026	**$5.95**
8GB MICRO SDHC CARD WITH SD CARD ADAPTOR	XC-4983	**$14.95**
HEADER TERMINAL STRIP	HM-3211	**$0.85**

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L293D QUAD HALF H-BRIDGE MOTOR DRIVER ZK-8880

Four high power outputs to drive a 1 x stepper or 2 x DC motors. 3.3V or 5V.

$27.95

PCB ETCHING KIT HG-9990

Complete with assortment of double-sided copper boards, etchant, working bath and tweezers.

FROM $6.95

JUMPER LEAD KITS

Ideal for connecting devices for testing. 10 leads supplied.

STANDARD WC-6010 **$6.95**
HEAVY DUTY WC-6020 **$11.95**
RETRACTABLE WT-5334 **$29.95**

FROM $5.45

RELAY BOARDS

Provides the easiest way to use your Arduino® project to switch real world devices.

- Status LEDs show channel status
- Screw terminals for easy connection to relay contact

1 CHANNEL 5VDC XC-4419 **$5.45**
4 CHANNEL 12VDC XC-4440 **$12.95**
8 CHANNEL 12VDC XC-4418 **$19.95**

FROM $4.50

PC BOARDS - VERO TYPE STRIP

Alphanumeric grid, pre-drilled 0.9mm, 2.5mm spacing.

95MM(W) X 75MM(L) HP-9540 **$4.50**
95MM(W) X 152MM(L) HP-9542 **$7.95**
95MM(W) X 305MM(L) HP-9544 **$11.50**

$8.95

SPOT FACE CUTTER FOR STRIP BOARDS TD-2461

Designed to neatly remove copper track on strip type prototyping boards.

- 110mm long

$13.95

ANTI STATIC WRIST STRAP TH-1780

- Adjustable hook and loop wrist strap
- Coiled lead and banana plug/alligator clip
- Expanded lead length approx 1.8 m.2.

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ISOPROPYL ALCOHOL NA-1066

Many uses such as head, surface, prep, and contact cleaning plus, stain removal in the laundry etc.

- 99.8% concentration
- 250ml pump spray

MEASURE TEMPERATURE & MORE

NOW $199
SAVE $50

PRO HIGH TEMPERATURE NON-CONTACT THERMOMETER
QM-7226 **WAS $249**

Measure high temperatures with safety. Supplied in a robust blow-moulded case.

- Laser pointing targeting
- Temp range: -50 to 1000°C
- 30:1 distance-to-spot ratio
- 230(L) x 100(H) x 56(W)mm

FROM $119

USB TEMPERATURE & HUMIDITY DATALOGGERS
Log, read and store data in internal memory for later download to a PC.

- Temp range: -40 to 70°C (±1°C)
- Humidity range: 0 to 100% (±3°C)

DIRECT PLUG-IN QP-6013 **$119**
USB/LCD READOUT QP-6014 **$149**

$29.95

DIGITAL STEM THERMOMETER
QM-7216

Features fast response, min/max memory and data hold. Stainless steel probe, splashproof body. LR44 battery included.

- Range: -50 - 200°C / -58 - 392°F
- 5000 hour battery life
- 205mm long

$39.95

DIGITAL THERMOMETER WITH K-TYPE THERMOCOUPLE QM-1602
Excellent measurement range and a hold function to lock the reading on the display. Thermocouple and 2 x AAA batteries included.

- 3.5 digit LCD display
- Range: -50 - 750°C
- 128(L) x 61(W) x 25(H)mm

Please note: Measuring up to 750°C will require the use of an additional thermocouple probe available separately (QM-1282)

$14.95

K TYPE THERMOCOUPLE PLUG IN PROBE QM-1282
Allows measurement of external temperature readings on DMMs.

- Measures temperatures from below minus 50C to over 250C
- Suitable for gas and liquid with accuracy of 0.75%

ALSO AVAILABLE:
WIRE TYPE K THERMOCOUPLE
QM-1283 **$11.95**

$11.95

WIRE TYPE THERMOCOUPLE WITH TWIN BANANA PLUGS
QM-1284

Similar to our other thermocouples, this one is fitted with banana plug terminations but does not have a `probe' assembly.

- Typical thermocouple measurement range from as low as -50°C to over 250°C

SOLAR POWER METER
QM-1582 **WAS $129**

Optimises solar panel installations by finding optimum locations for the panels. Expressed as W/m2 (Watts per square metre), or BTU/ft2 (British thermal units per square foot). Includes carry case.

- Powered by 3 x AAA batteries (included)
- 63(W) x 162(H) x 28(D)mm

NOW $99
SAVE $30

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SAVE $20

TRUE RMS AC 3000A FLEXIBLE CLAMP METER QM-1568 **WAS $119**
Features a flexible "clamp" loop that unclips on one side. Min/max, data hold & backlit LCD. CATIII 1000V and CATIV 600V rated.

- Autoranging
- 2 x AAA batteries included
- 105(W) x 270(H) x 28(D)mm (when closed)

NOW $149
SAVE $20

PRO DIGITAL LIGHT METER
QM-1584 **WAS $169**

Uses photopic spectral sensitivity which closely mimics the response of the human eye to changes in light. Measurement can be switched between LUX and FC (foot candles). Carry case included.

- Long-life silicon photo diode sensor
- Min & Max measurements
- Easy to read backlit display
- Data hold

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SAVE $30

PRO SOUND LEVEL METER WITH CALIBRATOR
QM-1592 **WAS $379**

Ideal for vehicle traffic or aircraft noise testing, race scrutineering, or any evidence-based noise testing. Includes a calibrator to verify your results.

- A & C weighting scales
- AC & DC analogue outputs
- Min/max measurement
- 278(L) x 76(W) x 50(D)mm

$34.95

MOISTURE METER - WOOD & BUILDING MATERIALS QP-2310
An intelligent meter with 8mm electrode suitable for measuring water content in building materials and wooden fibre articles.

- Range: 6 to 44% (Wood) / 0.2 to 2.0% (Material)
- 96(H) x 40(W) x 20(D)mm

$24.95

MAINS POWER METER MS-6115
Shows how much an appliance is costing to run and tracks the total power being used. 10A max rating.

$34.95

POWER POINT AND EARTH LEAKAGE TESTER QP-2004
Assess the safety of installed main sockets and earth voltages and identify dangerous electrical installations. IP65 rated enclosure.

ALSO AVAILABLE:
INLINE RCD CIRCUIT BREAKER
QP-2002 **$34.95**

FROM $24.95

SELF-POWERED LED PANEL METERS
Simple 2 wire connection for voltage readout. Auto zero calibration and easy to read display. Automatic polarity sensing. Cutout size 42 x 23mm.

LED VOLTMETER 8-30VDC QP-5586 **$24.95**
LED AMMETER 0-50ADC QP-5588 **$39.95**

$69.95

DIGITAL DC POWER METER MS-6170
An ideal addition to any low voltage DC system this digital power meter features real time display of the voltage, current draw, and power consumption. Includes internal shunt.

- 5-60VDC
- 45(W) x 75(L) x 23(D)mm

IT'S NO FLUKE, OUR DMM'S ARE BETTER VALUE

VIEW THE FULL RANGE OF DIGITECH DMMS:
www.jaycar.com.au

Built for precision and reliability the mid to advanced range of DIGITECH Digital Multi- Meters (DMM) come with LIFETIME WARRANTY, delivering the same measurement precision as other more expensive brands, but at a fraction of the price, making them better value and an excellent choice for professionals in the field or workshop.

The table here is proof why we believe your next DMM has to be a DIGITECH. At less than half the price of its name brand rivals, the DIGITECH QM-1549 packs all the key features to meet the needs of the most demanding professional.

COMPARISON TABLE:

	QM-1549	FLUKE 117
DC Voltage Reading	400mV – 1000V (0.5% accuracy)	600mV – 600V (0.5% accuracy)
AC Voltage Measurement	True RMS	True RMS
AC Voltage Reading	400mV – 1000V (0.8% accuracy)	600mV - 600V (1% accuracy)
Resistance reading	400 Ω – 40 MΩ (0.8% accuracy)	600 Ω – 40 MΩ (0.9% accuracy)
Safety Rating	CAT IV (600V max)	CAT III (600V max)
IP Rating	IP67	IP42
Warranty	Lifetime	3 Years
Price	**LESS THAN $100**	**MORE THAN $300**

ENTRY LEVEL
FROM $9.95

AFFORDABLE WITH TRANSISTOR & DIODE TEST QM-1500

Perfect first meter! Includes transistor, diode test & test leads.

- 2000 count
- CATII 500V
- AC/DC voltages: 750V/1000V
- 10A DC only
- 125(H) x 689(W) x 23(D)mm

$9.95

AUTORANGING WITH NON-CONTACT VOLTAGE DETECTION QM-1529

Exceptional value for money. Measures both DC and AC voltages and currents. Continuity, diode and data hold. Includes test leads.

- 2000 count
- CAT 111 600V
- AC/DC voltages: 600V/600V
- 10A AC/DC
- 144(L) x 70(W) x 32(H)mm

$24.95

AUTORANGING WITH TEMPERATURE

QM-1323

A budget-priced meter with everything you need - capacitance, temperature & 10A on AC & DC. Duty cycle, data hold, relative measurement etc. Includes test leads.

- 4000 count
- CATIII 600V
- AC/DC voltages: 600V/600V
- 10A AC/DC
- K-probe and case included
- 137(H) x 65(W) x 35(D)mm

$49.95

MID RANGE
FROM $69.95

TRUE RMS WITH TEMPERATURE & NON-CONTACT VOLTAGE DETECTION

QM-1551

True RMS for higher accuracy. Measures AC and DC (600V), and current (10A). Includes test leads.

- 4000 count
- CATIII 600V
- AC/DC voltages: 600V/600V
- 10A AC/DC
- K-probe included
- 138(L) x 68(W) x 37(D)mm

$69.95

TRUE RMS AUTORANGING - MINI

QM-1570

Compact, IP65 (weather resistant). Drop tested from 2m height. Includes test leads and carry case.

- 4000 count
- CATIII 600V
- AC/DC voltages: 600V/600V
- 135(H) x 70(W) x 45(D)mm

$89.95

TRUE RMS AUTORANGING - IP67

QM-1549

Large, easily read display and carries an IP67 environmental rating. Includes data hold, diode test, relative measurement etc. Includes test leads and carry case.

- 4000 count
- CATIV 600V
- AC/DC voltages: 1000V/1000V
- 10A AC/DC
- IP67 waterproof
- 182(L) x 82(W) x 55(D)mm

$94.95

ADVANCED
FROM $129

TRUE RMS AUTORANGING WITH WIRELESS USB INTERFACE

QM-1571

Wireless USB interface and included logging software allows for computer based live data logging whilst keeping your computer completely isolated and protected. IP67 waterproof, duty cycle, data logger, relative measurement etc. Includes test leads.

- 4000 count
- CATIV 600V
- AC/DC Voltages: 1000V/1000V
- 10A AC/DC
- 170(L) x 79(W) x 50(H) mm

$129

MULTIFUNCTION ENVIRONMENT METER

QM-1594

Combines the functions of a sound level meter, light meter, humidity meter and temperature meter. Non contact voltage.

- 4000 count
- CATII 600V
- AC/DC voltages: 250V/250V
- 170(H) x 78(W) x 48(D)

$129

CAT III INSULATION TESTER/ MULTIMETER

QM-1493 **WAS $269**

Commonly known as a megger and suitable for high voltage insulation testing up to 4 gigaohms at up to 1000V. Analogue/digital display, data hold. Includes test leads.

- 4000 count
- CATIII 1000V
- AC/DC voltages: 750V/1000V
- 200(L) x 92(W) x 50(D)mm

$249

SAVE $20

See terms & conditions on page 8.

WORKBENCH ESSENTIALS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

1. 100MHZ DUAL CHANNEL OSCILLOSCOPE QC-1936 **WAS $899**
- 7-inch colour-LCD
- Waveform generator
- PC connection via USB
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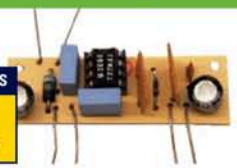

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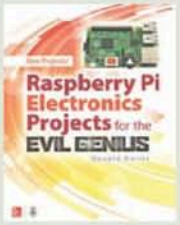

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SERVICEMAN'S LOG

Rangehood repair full of red herrings

Dave Thompson*

No matter how good you are or how much experience you might have, sometimes servicing just comes down to luck. That can mean good luck, where you take apart a monstrously complex device and immediately spot the simple problem which is preventing it from operating. Or bad luck, when you are trying to repair the simplest device and nothing you try seems to help. This is the second kind of story.

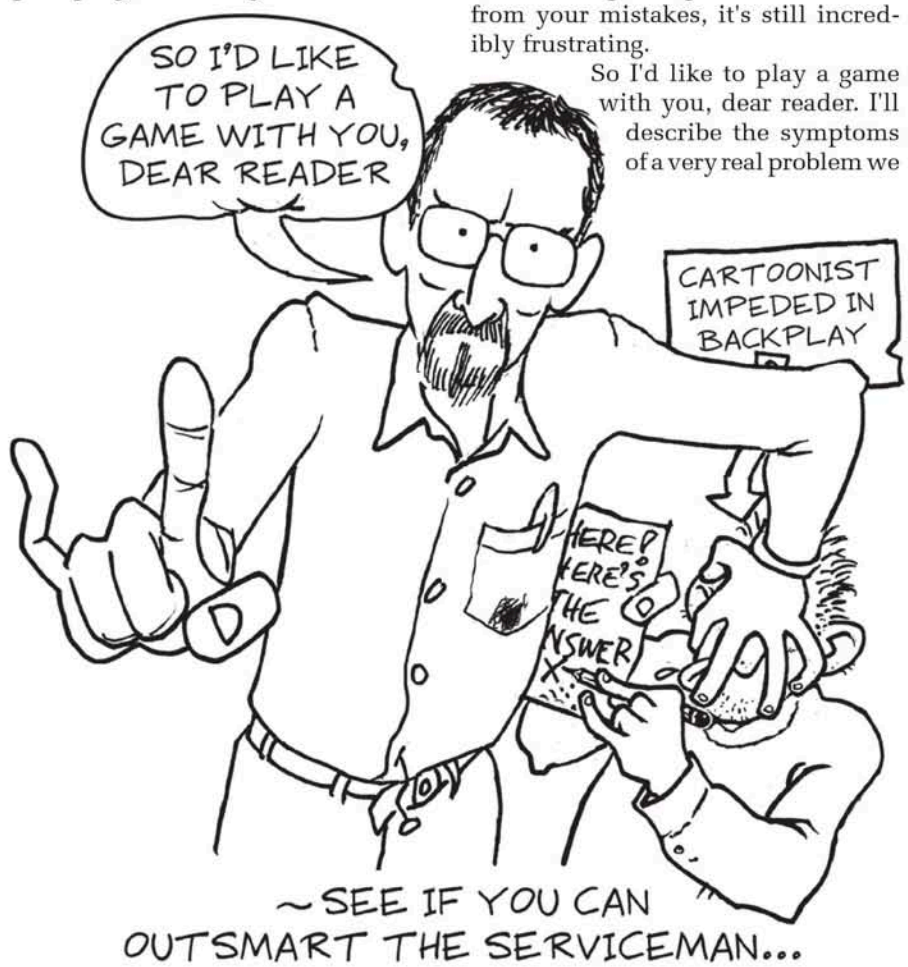
I've had some brilliant successes but more than once, and especially lately, I've completely misread clues and then made assumptions that steered me away from the true cause of a problem.

Once, I stripped a lawn mower motor down to the block, looking for all manner of non-existent faults, when all I needed to do was change the spark-plug; something even the least-experienced DIY enthusiast knows is the first thing to check!

Another time, I stripped every nut and bolt from a vacuum cleaner in order to disassemble it when just a few screws held it all together — I just didn't twist it the right way to pull it apart.

We've pretty much all had this kind of experience and while you just have to chalk it up to experience and learn from your mistakes, it's still incredibly frustrating.

So I'd like to play a game with you, dear reader. I'll describe the symptoms of a very real problem we had with our just one-year-old range hood and see whether you can guess what was wrong while you're reading through all the trouble-shooting I did, which only served to demonstrate what wasn't wrong with it.



The appliance in question is a Robin Hood Range Hood, model RWV3CL6G. It was installed almost exactly one year ago, having been purchased brand new from a local big-box store. It wasn't even at the age of a toddler yet but was already starting to spit the dummy.

This particular model has five illuminated buttons along the front panel (called "sophisticated electronic controls" in the user manual) to control the fan and the two 24V, 1.5W LED downlights in the front corners. The buttons turn a function on with one press, and off with another, each time accompanied by a soft beep.

A blue LED backlight indicates the button's state; illuminated when on and dark when off. The buttons are positive, tactile and worked well, and the three-stage fan and LED lights were both powerful and efficient.

We use this appliance frequently. It sits directly over a gas hob in the kitchen and is vented to the outside world through the wall, via a short piece of steel ducting.

Items Covered This Month

- A rangehood of repairs
- MIG welder repair

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Email: dave@pcanytime.co.nz

All is not well in the serviceman's abode

A few weeks ago, while cooking, and with the fan and lights on, the LEDs flickered in unison before coming back to full brightness. I switched them on and off a few times and they still operated normally, being flicker-free for the next few days. I put that event down to a one-off power issue and forgot all about it.

Less than a week later, though, the same thing happened again, with both lamps dimming to a dull glow before coming right. The following day, I switched the lights on and halfway through cooking our meal, they dulled down and then went dark altogether.

Of course, this had to happen just a few weeks after the (rather short) warranty ended. Like many others, I suspect companies choose their components very carefully so as to maximise the chance this sort of thing happening, so you have to run out and buy another one... and another... and another.

Many of my own customers have often joked that computer manufacturers must install a timer into their machines so they fail just out of warranty. All joking aside, though, it does seem awfully coincidental and convenient for the manufacturer...

So, both LEDs were not working. Pressing the light control button still resulted in a beep and the blue LED lit up but there was no light output. Occasionally, when switching on, the LEDs would flash at full brightness but almost instantly go dark again. This always happened to both lamps at the same time but after this, for the most part, there was no output at all.

So here's the fun part. What do you think? What would you have done, which parts would you have blamed from such a fault? See if you can outsmart the serviceman and figure it out before the end of the story.

Given these symptoms, I suspected the LED driver. One lamp behaving badly might be a failing LED, but both behaving in an identical manner? And anyway, surely LEDs would last longer than this, while drivers can fail quite early due to dodgy electrolytic capacitors, voltage spikes on the power lines or various other woes.

Much wasted effort later

Pulling the thing apart was relatively simple but the fact it is stuck to the wall above the hob introduced some access issues. I disabled power to it at the breaker board before removing the lamp assemblies. These were held in using clip springs and simply needed to be prised out with something flat and thin.

Once out of the housing, the LED units hung on their respective power cables. The lens and reflector assemblies were held together in a bayonet-style fitting; a quick twist anti-clockwise separated the lens, reflector and the brushed-aluminium trim ring, revealing a G4-type LED.

The heavy-duty lamps were virtually all aluminium heatsink, with the LED die itself set into the very end. Rated as being equivalent to a 15W incandescent bulb but drawing just 1.5W, I was reasonably sure that they were bulletproof, and with no signs of overheating, I set them both aside and dug further into the hood's internals.

Removing the aluminium filter from underneath gave both better access and more light, so I could at least see what was going on. This model range hood has a thick, curved glass canopy, which is held onto the body of the appliance with four large set screws.

To get to these screws, I had to remove the stainless-steel chimney, which is a three-sided cover that conceals the fan, output ducting and electronics.

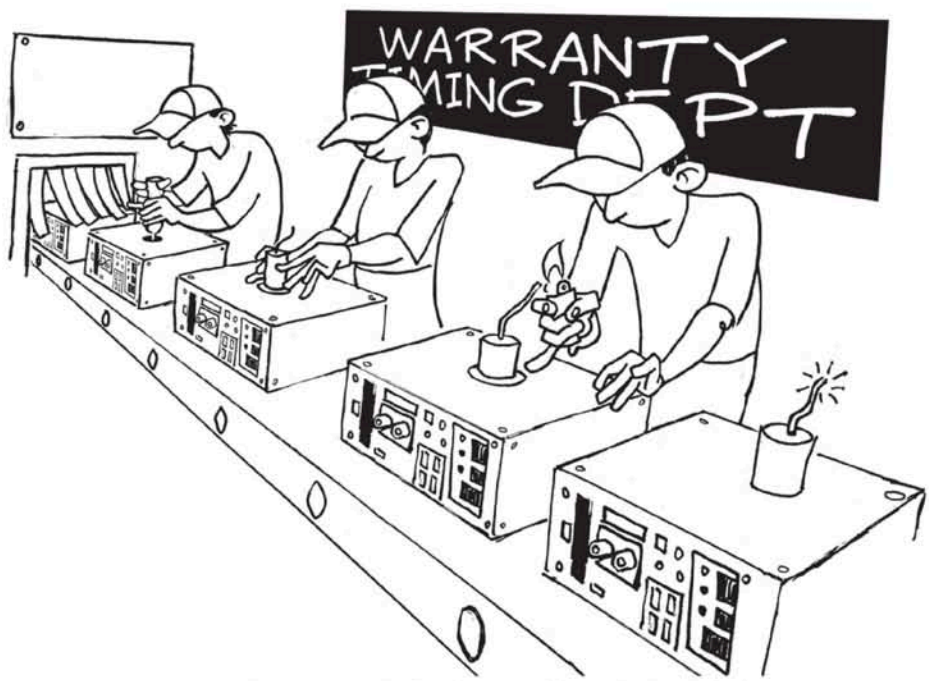
It is simple enough to remove the two small PK screws holding it in place but awfully fiddly to get free due to it being right at the ceiling and with me not wanting to stand on the benchtop or gas hob.

A bit of wiggling around (and cursing) got it free, but I wasn't looking forward to having to get it back up there; we'd had issues lining it all up when we first installed it, and there were two of us on the job back then.

Still, I'd cross that bridge when I got to it; all I could do now was carry on and find out why these lamps weren't working.

With the panels and canopy off, I had a clearer view of the internals. The front switch panel was connected with a ribbon cable to a controller circuit board further back in the guts of the range hood somewhere. To get to the board, I'd have to dig deeper. However, right in front of me, mounted on the shoulder of the main frame, was the LED power supply/driver.

This unit was smaller than I expected, being only about 30 x 30mm and around 20mm thick. It had a two-pin terminal block for mains power input and a similar terminal block that the dangling LED holders were wired into. It only had to deliver 3W in total, so I guess it didn't need to be very large.



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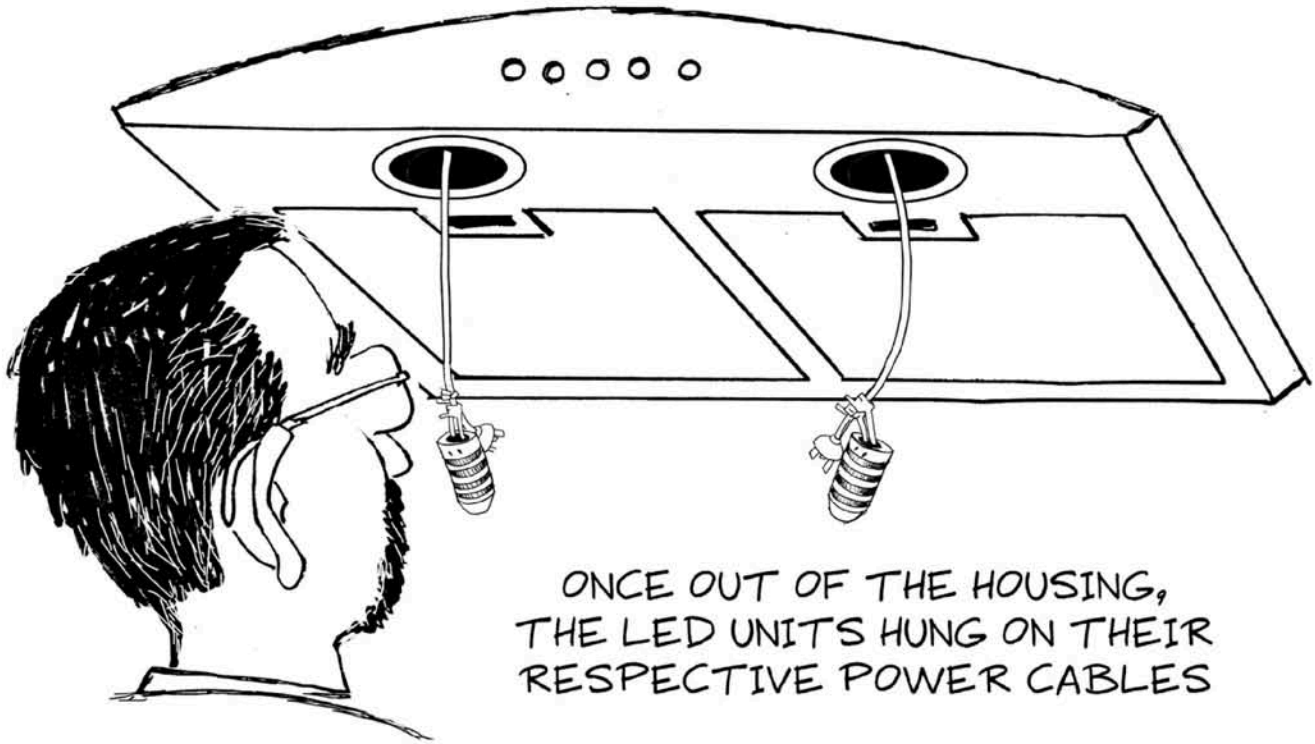


With the driver nicely accessible, I broke out my multimeter and, ensuring all the wiring was in a relatively safe state, restored power. I pushed the light switch, saw that the blue LED lit up and with my meter sitting on the kitchen benchtop, I carefully measured across the input terminals of the driver. The meter read around 230VAC on the 250V scale, which was close enough for me.

Add cornflour to plot, stir until it thickens

I use an analog meter for this type of work, as it is easier for me to read a meter needle position than having to read and understand a numerical value. So after adjusting the meter range, I measured across the driver's output. Hmm, I got 24V; I was expecting nothing, or thereabouts. Still, it might be intermittent so I switched it on and off a few times, checking each time. getting a stable 24 volt output. Curious.

After powering things down, I reinstalled the bulbs into their respective holders. This time, when I pushed the light switch, for a brief moment, both bulbs lit up to full brightness before going dark again. What was going on here? With the light switch on, I set about wiggling and measuring in equal amounts, but aside from the briefest of dull glows, they remained stubbornly dark.

Somewhat puzzled, a notion was beginning to poke its way through to the front of my mind; after all, despite the appearances of the LEDs, there could only be one explanation, given the results of these tests.

To confirm my diagnosis, I took out the LEDs again and departed to my workshop, where I broke out my benchtop power supply. After carefully setting the output to 24V and limiting the current to about 100mA, I connected each LED up to the supply using small, alligator-style clips. As had slowly dawned on me, neither bulb showed any sign of life.

Actually, that's not quite true; once or twice, as power was applied, I saw the briefest of glow from the LEDs. If I interrupted the supply by touching and releasing one leg of the LED, I could very infrequently get a full-brightness flash, almost like a flash-gun, from one of the bulbs. In laymans' terms, they were both poked.

How could I be so thick? A simple bulb failure, and here I am with the range hood lying all over the kitchen bench. Both bulbs gone, failed at exactly the same time and exhibiting (for all intents and purposes) exactly the same symptoms. Apparently, failed LEDs can show full brilliance for short periods of time. I know this seems unbelievable, even unlikely, but I assure you I've described things exactly as they happened.

If only one bulb had failed and had flickered from full brightness to a dull glow, I would have assumed that bulb had failed and simply replaced it; a five-minute job (if that) which doesn't involve disassembling the range hood into component parts. To my mind, both LEDs exhibiting exactly the same behaviour as they failed beggars belief.

Surely, the driver had something to do with this? Perhaps it surged and took the LEDs out, fooling me into thinking it had failed instead. To determine if this was the case, I removed the two screws holding the driver to the frame and took it out to the workshop, where I proceeded to connect some strip LEDs I had on the bench and powered them up using mains power input, just as it would be in the range hood.

I ran the strips for about an hour at full power, monitoring the voltage output and current, and everything was as stable as could be expected. Annoying to say the least but at least I know the driver likely had nothing to do with anything, and it is just a LED failure, pure and simple.

An easy fix. Or is it?

Well, this one really got me good. Hopefully, I'll be a bit more aware in the future but the way these LEDs failed is a new one on me.

Now all I had to do was find some replacement LEDs and get the range hood reassembled. But finding replacement LEDs turned out to be tougher than putting the range hood back together.

The only G4 LEDs I could find locally (and when I say locally I mean within New Zealand) were listed on a campervan manufacturer's website at a whopping $43 each! Needless to say, I wasn't paying those daylight robbers anything like that for a LED. After a few more wild goose chases, with similar results price-wise, I decided to try my luck over at AliExpress.

Sure enough, there were hundreds of listings of G4-type LEDs, the vast majority being replacement lamps for chandeliers and cove lighting. But they would likely be suitable for our needs as well.

The LEDs I ended up buying have a 12-24V AC/DC input range and are rated at 3W each. The cost was just US$7.80 for a pack of six. While they might be a little over the top for a range hood, there was nothing with a lower power rating that I could find with a G4-style connector.

We put up with not having lights in the range hood until the new LEDs arrived. They are actually rather impressive in the flesh. For a start, they are quite large; at 15 x 45mm they are about 10% larger than the originals, and therefore barely fit into the receptacles in the range hood.

However, they are also flexible, being made out of some kind of amazingly-clear and pliable silicone material, so a bit of fettling got them fitting OK. However, it appears I didn't choose well, as the driver won't power up the new LEDs.

All I get with one LED plugged in is the LED flashing at full brightness at about two hertz. I didn't want to try plugging both LEDs into the driver since that would be a 6W load and as far as I know, it's only designed to handle the original 3W worth of lamps.

I tried powering the new LEDs with my benchtop supply, thinking perhaps I'd purchased blinking LEDs by mistake but I found that even at 10V and 20mA, they easily lit up. So perhaps there is something awry with that driver after all.

That said, it did test out OK, powering up the strip lighting with no apparent problems, so it is more likely just a mismatch between it and the new LEDs that leaves it unable to power them properly.

Regardless, I'll have to either replace the LEDs or find another driver. After another quick look on AliExpress, I found a new driver that should do the job. While a little bit larger physically, it will still easily fit in the space for it within the range hood, and with an output of 12V and 2A, it has more than enough grunt to drive these two LEDs at full noise all day long.

At just US$4.50 with free shipping, it is also affordable and, I think, a reasonable upgrade to the range hood. It is yet to arrive, but I have no doubt it will be the answer to this whole problem.

So once again it seems I overthought what turned out to be a stupidly-simple fault. In my defence, given the symptoms and the fact that both bulbs failed at exactly the same time, I didn't even consider the LEDs could be the issue.

I expect LEDs to last a lot longer than a comparable halogen or incandescent bulb of similar output, as per all the marketing hype, and to have them fail at just over a year with very little actual use is a big disappointment.

I would guesstimate that, on average, they haven't been used for more than a couple of hours a week over that year, resulting in a lifespan of only around 100 hours.

And I consider a replacement price after such a paltry life of 40 plus bucks each a huge rip off. The pair of halogen bulbs in our previous kitchen's range hood only needed to be replaced twice each in 10 years and likely had more use than the LEDs in the range hood at this house, so either we got unlucky, or we got burned. Time will likely tell which it is.

Well, I hope you enjoyed playing "outsmart the serviceman" and I'm sure many of you made better guesses than I did initially. At least I'm on the way to having this one sorted but really, you'd think that replacing a lamp would be an easy job for an old hand like me.

Metal inert gas (MIG) welder repair

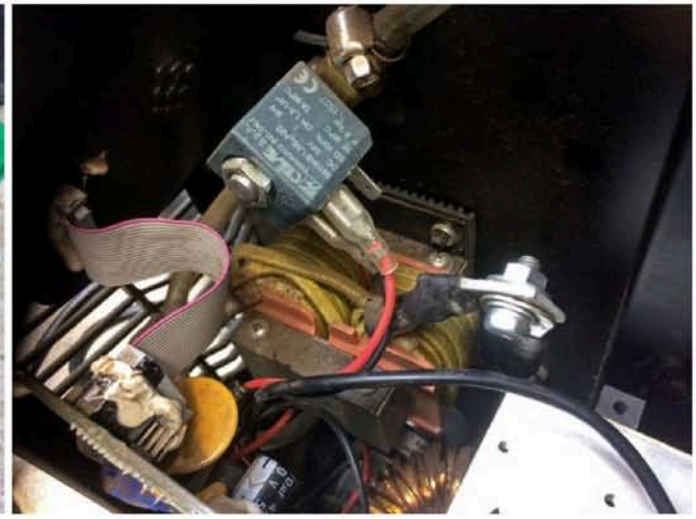
The next story is from M. H., of Albury, NSW who had to first reassemble and clean out what was left of a MIG welder before he could even have a go at fixing the fault which left it in this sorry state. His story is as follows:

My friend's mate gave him a MIG welder that was not working and he asked me to fix it. When I first looked at the beast, it appeared that lots of different people had previously had a crack at getting it going again.

The handover ceremony involved the presentation of an ice-cream container of assorted parts along with the statement "It's beyond us, Mike. If you can get it going, it is yours!"

I own a handbag-sized IGBT welder with rod and TIG options and at the time, had developed just enough skill for backyard, weekend-warrior type

The control knob is connected to a stepped rotary encoder on the front display PCB. The mounting pins were repaired and copper wires added to provide anchoring.



At a glance everything in the power section of the welder looked like it would work OK, until it was switched on. The fault lay on the main PCB.

welding. I had observed professional welders using a good MIG unit, but when I investigated the cost, I decided I really did not need one. Well, this was my opportunity to gain a working MIG unit as well as further my skills at saving stuff from the landfill.

The broken unit I was given is a BOC Smootharc 180 MIG Welder. MIG stands for metal inert gas and it works by feeding a wire out of the handset end to maintain the arc and also provide the metal for welding. A gas is simultaneously discharged under the hood around the arc to exclude oxygen, which would prevent a proper weld from forming.

You can also use "gasless" wire that contains a material which vaporises, providing the same oxygen displacement protection as the inert gas would. This has the advantage that you don't need to rent a gas bottle, lug it around or have it periodically re-filled.

Anyway, having decided to fix it, I placed the unit on the bench in my workshop and attacked the obvious faults first. No need to remove the cover; it was already in the ice-cream container.

I cleaned out all the bent and melted tips from the wire feed compartment. It seemed that this side of the unit has been used as dumping ground for busted parts.

I then checked the action of the motor drive for the wire feed by manually turning the motor parts and all seemed okay. The other half of the casing contains the main circuit board and it was lined with dirt and dust and metal shavings from years of grinding near the unit.

Evidence of attempted repair action was everywhere. The main heat sinks were floating free off the board. The IGBT drivers were floating free and there were broken wires on the gas solenoid. Transistor clamps had also been removed and a heat-sensing thermistor had been torn from the mountings.

What a mess! It was going take a lot of work to put everything back in place before this baby got mains power connected again.

The front of the unit housed a control knob to vary settings on the display, which was broken and wobbling free. It was connected to a stepped rotary encoder. The shaft retaining pins were broken and it required some restoration work and wire strips added over the base unit to give it strength.

With all the obvious faults restored, it was time to review what this thing was actually capable of doing. 15A mains power passes through a tough-looking mains filter to keep the noise inside the box from getting out on the mains and then immediately through two large bridge rectifier blocks and then off to the main board via oversized red and black wires.

A thick cable runs from a very large heatsink to a lug terminal secured by a 10mm bolt, to connect the welding cable to the front of the unit. The other work cable passes though a large toroidal coil and then through what looked like a final filter. I assumed this section basically operated as a "buck" step-down converter, but that's unimportant at this point.

Since all was looking good and clean, and everything appeared to be in place, it was time to "light this thing up". So with mains on, the fans were running and display on. Good. The knob varied the display numbers. Pressing the wire feed button caused the wire to spool out. All was looking great.

I pulled the trigger on the handset and tapped the work clamp with no result; no sparks, no action. I now had the original fault to chase.

What should have happened when I pulled the trigger was that the wire feed motor should have started. When the wire hits the workpiece, this should cause the current to flow, creating the welding arc. But tapping the wire to the workpiece produced nothing. It was time to visit the main board and inspect it further.

I am always pleased to see design-

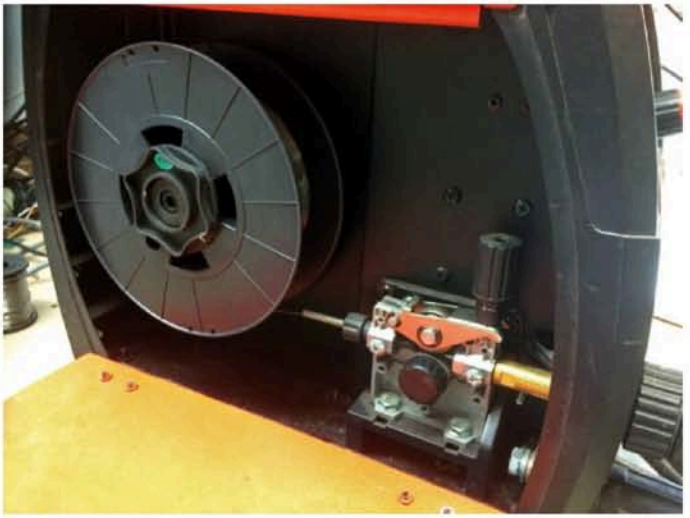
Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

This interior shot of the MIG welder shows the main control PCB and the power supply filter board above it. The failed component is at lower left; see the close-up image below.



The wire feed motor is mounted at the opposite end of the case. One of the symptoms of the fault was that it did not operate when expected.

ers of equipment using LEDs on the boards to indicate conditions. A LED blinked when I tapped the wire to the work, so clearly it was detecting this action. But nothing happened when the trigger was pulled.

I then investigated if there was a fault in the trigger or handset. Using my old faithful Dick Smith analog multimeter it was easy to prove the trigger signal arrived at the main board.

Near the connector for the trigger was a cluster of resistors, a transistor and a few diodes to form what looked like a trigger detection circuit. Its output was fed to an opto-isolator.

I powered the unit up again and measured the voltage across the input side of the opto-isolator, which revealed 14V when closer to 1V should have been present, ie, the forward voltage of its internal infrared LED.

So this LED must be open circuit. A quick Google search showed that the opto-isolator was nothing special and just had the typical transistor output. As I am a "throw nothing out" sort of guy, a quick search in the junk pile revealed a replacement. I used a heat gun to de-solder the SMD opto and the replacement was soon in place.

At last, I was ready to apply mains again. The fans ran, the LED displays came on and the unit seemed ready. So to test it I tapped the wire to the work and pulled the trigger.

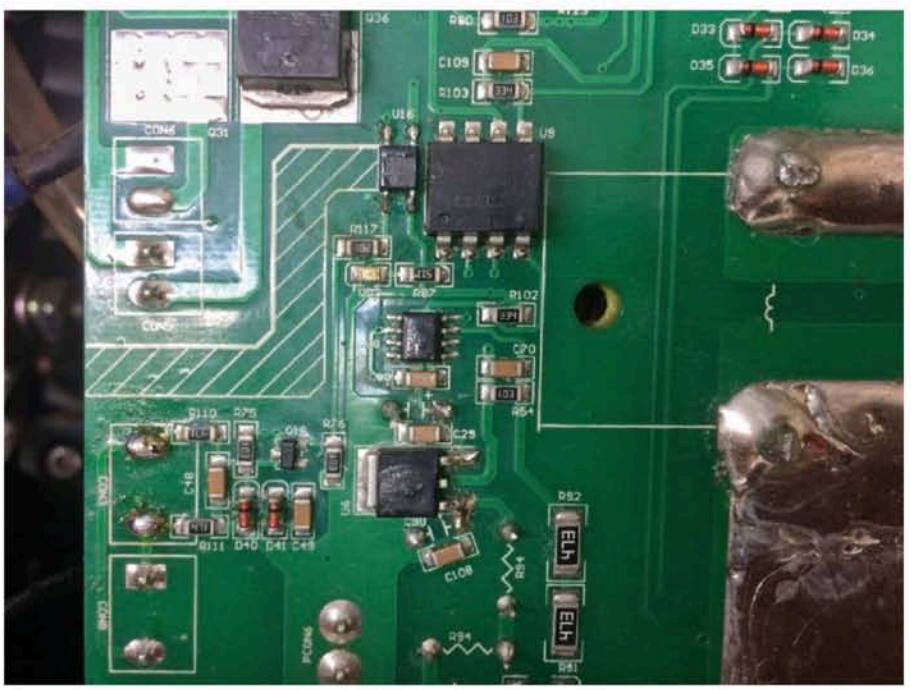
Sparks flew everywhere and red dots dashed about on the floor. The carpet mat at my feet was smoking with burn holes. Wire was feeding out of the handset. It was like Christmas on Black Saturday and my workshop filled with smoke. I decided that perhaps I should control the situation a little better before the next strike on the work clamp.

To control the wire feed, I removed the drive clamp. This will allow the motor to drive without feeding wire out of the handset. I then pulled the trigger and viewed the main controller board. Lots of LEDs blinked, indicating the IGBT driver section was operating and output was present. When the trigger was pulled, the output floated about 20V.

It was now time to move outdoors to make more smoke and try melting stuff. It all seemed to do what it should, so I was convinced it was time to visit a friend that has a proper MIG to compare with my now-working unit.

It compared well, so the conclusion is that this wonderful beast had been brought crashing down by the failure of a 20¢ opto-isolator and was almost relegated to the dump because my mates tried to fix it by "just undoing stuff" with no real idea of what the fault may be.

Luckily I managed to rescue it! **SC**



The faulty opto-isolator is near the top of the photo (U16), while the hand trigger switch connectors are at lower left (CON3). Both solder joints had blown for some reason or another.

Do-it-yourself Bass Guitar Kit

Building your own guitar has a real attraction for many musicians. But normally, left-handers are left right out! Here's a complete kit that comes with all the parts needed to build, string and get playing your own electric or bass guitar.

If you've been frequenting the internet lately, you may have noticed a lot of advertisements from Banggood and similar outfits, of interest to readers of this magazine.

Most of the items are electronic gadgets but recently I started seeing intriguing ads for DIY electric guitar kits. These provide you with all the necessary wood, electronics, strings etc; it's then up to the purchaser to do the assembly, nut and bridge adjustments, connect the internal electronics and so on, but most importantly, apply the finishing coat to the woodwork.

One common query I noticed was: "Do you make left-handed versions?" and it was clear from the sometimes nonsensical answers that the good people at Banggood had no idea what was being asked!

I play left-handed and after doing some research, I found that the only company who appear to offer left-handed bass kits are Pit Bull Guitars (www.pitbullguitars.com), based in Western Australia. I also discovered that, once exchange rates and shipping are taken into account, the Pit Bull products work out to be only slightly more expensive.

But Pit Bull offer a much bigger range of models and build options, plus you get the benefit of local, English-language backup.

They even host a builders' support website: www.buildyourownguitar.com.au/forum

Pit Bull's main line of business is supplying fully-finished guitars to music shops in Australia, but clearly they thought there was also a market for enthusiasts who wanted to "roll their own".

So they appear to be just supplying the same kit of parts that their Chinese factories use to assemble their fully-finished products. There are a few other places in Australia who also offer DIY guitar kits, but none appear to have anything like Pit Bull's range.

I've always wanted to own an electric bass but left-handed models of reasonable quality are hard to come by and not particularly cheap. Pit Bull have a range of 14 different left-handed guitar models, including three basses, and I chose the JB-4L, "inspired" by the Fender Jazz Bass, as played by

Some of the parts included in the kit, from left to right: pickguard, two pickups, bridge with saddle, volume & tone controls, nickel-plated strings, tuning pegs, assorted screws plus nuts and backplate cover.

By Keith Walters

Michael "Flea" Balzary of the Red Hot Chili Peppers.

The JB-4L kit costs just $199 including shipping anywhere in Australia. So I clicked the appropriate boxes, hit the PayPal "Pay Now" button and Australia Post delivered it a few days later.

It came adequately packed in a stiff carton with lots of ecologically-correct cardboard and paper padding. The screws were all sealed into pockets in one plastic bag with no identification; you have to work out where they go. All the other bits are sealed in their own separate plastic bags.

There are also no real assembly instructions; Pit Bull suggest you visit their website for that. They do recommend you carry out a "mock build", basically placing all the parts in their approximate positions to check that everything is there, but that's pretty much it.

I did all that and after confirming that everything was there, immediately started the assembly. There are actually four main parts to the process and there is no specific order in which they need to be done (although this is for a bass, the instructions are pretty much identical for a 6-string guitar apart from the extra two strings):

A. Metalwork assembly, basically getting all the mounting screw holes in the right places

B. Fitting and wiring up the electrical parts

C. Painting or otherwise finishing the woodwork

D. Adjustment of frets, action and intonation.

In my case I did them in the order above, which gave me a presentable guitar after step C. To be honest, if I'd know how little time step D was actually going to take, I probably would have done it A-B-D-C. Normally, you would want to leave the finish until last, to avoid damaging it.

The first thing you need to do is attach the neck. Some people recommend temporarily clamping it in position when you're getting the rest of the components lined up, but I can't see any real value in that, at least with a bass, so I decided to screw it into place immediately.

The neck comes pre-drilled with four holes, and you first have to drill matching pilot holes in the body, which was where I ran into my first snag...

There is a metal backing plate that the screws are meant to pass through to spread the load. I left that off during

The neck of the guitar is attached to the body via a bolt-in joint, with four holes drilled through the body. This type of joint is quite strong, fairly easy to produce and doesn't require glue.

Preparing the holes for attaching the bridge (left) and one of the pickups (right). The bridge is the sheet of metal that is secured to the body, while the saddle is attached to the tail-end of the bridge and the strings then sit on top of the saddle. The type of bridge/saddle combination used in this guitar is called a Tune-O-Matic bridge. It is adjusted by tightening or loosening the screws, thus altering the tension the springs apply on the strings.

the drilling because I didn't want to scratch it, and when it came time for the assembly, I encountered this:

The screw holes on the backplate that thread through to the neck didn't align properly, as shown in the photo below.

I mentioned this on the forum, and another builder making the exact same "lefty" bass reported he had the exact same problem! So somewhere in China is a jacked-up drilling jig. Anyway Pit Bull say they are looking into it.

To be fair, they probably don't sell all that many JB-4Ls, and nobody has reported similar problems with other models. Fortunately, I found some bamboo skewers that were exactly the right size to fill the erroneous hole, and after gluing one of those in there I soon had the neck re-drilled and properly attached.

The next stage is fitting the bridge. There are various techniques described on the forum. I decided to use some cotton kitchen twine, normally used for tying up roasts and the like. I used this because it doesn't stretch and used Blu-Tack to secure two lengths of the twine behind the nut.

I marked the position of the 12th fret with a Texta pen, and then doubled the twine back and marked it where it passes through the nut (it's better if you can get someone to help with this). That way, the first mark should be at exactly half the scale length, and the second should be twice that (the actual required scale length).

We need to measure the scale length as it's used to help set the location of the saddle on the bridge, once the strings are attached.

I added some weights to the other ends of the twine so it hung over the end of the body, keeping the twine taut.

The reason for this is because the distance from the 12th fret to the nut is the same as the distance from the 12th fret to the bridge, plus some compensation depending on the type of bridge and other factors.

Then it's a simple matter of dropping the lengths of twine into the relevant slots on the bridge and moving the bridge around so that the twine lines up with the outermost pickups, and the pen marks line up with the centred adjustable bridge saddles.

I recommend you just drill two pilot holes at first to make sure the bridge hasn't moved, and re-check the alignment before you put the rest in.

Unfortunately, I subsequently encountered another snag! Despite one poster on the builders' forum stating that the bass bridge saddles should be centred exactly at twice the 12th fret distance as shown, it turns out for a bass, the bridge needs to be mounted another 5mm or so further away from the pickups. Otherwise you may not be able to get the intonation right.

Editor's note: This is typically due to the total string length being longer than the scale length to provide a buffer distance (about the distance the string bends when pressed to the fretboard), and is typically done by having the saddle set at an angle.

Intonation of the guitar

Editor's note: we recommend doing the body finish before attaching

The backplate had one misaligned screw hole, which meant that the hole had to filled and then re-drilled.

The 12th fret is marked in black on two pieces of cotton twine and we use the total distance from the nut to this marking to calculate half the total scale length for the guitar.

the electronics/strings and doing the intonation, as you will need to remove them before applying the finish.

Take for example the E string. You normally tune the guitar so that the "open" (unfretted) E string is tuned to, well, "E". Then, when you hold the E string down at the 12th fret and pluck it again, it should sound 12 semitones higher, that is, E again, but one octave above the open frequency.

The problem is, when you fret a string you're both tightening it, which will increase its pitch, and lengthening it, which will tend to lower it. Normally, stretching wins out, so if the 12th fret is positioned exactly halfway along the string, the fretted note will sound slightly higher than E.

You correct this by adjusting the individual saddles on the bridge with the adjustment screws. If the fretted note is too high, the saddle has to be moved away from the pickups.

This is complicated by the string "action" chosen, that is, how high the strings sit above the fretboard, since that affects how much the string has to be stretched during fretting. The action is adjusted using an Allen key they supply, with the small screws fitted to the bridge saddles (see later).

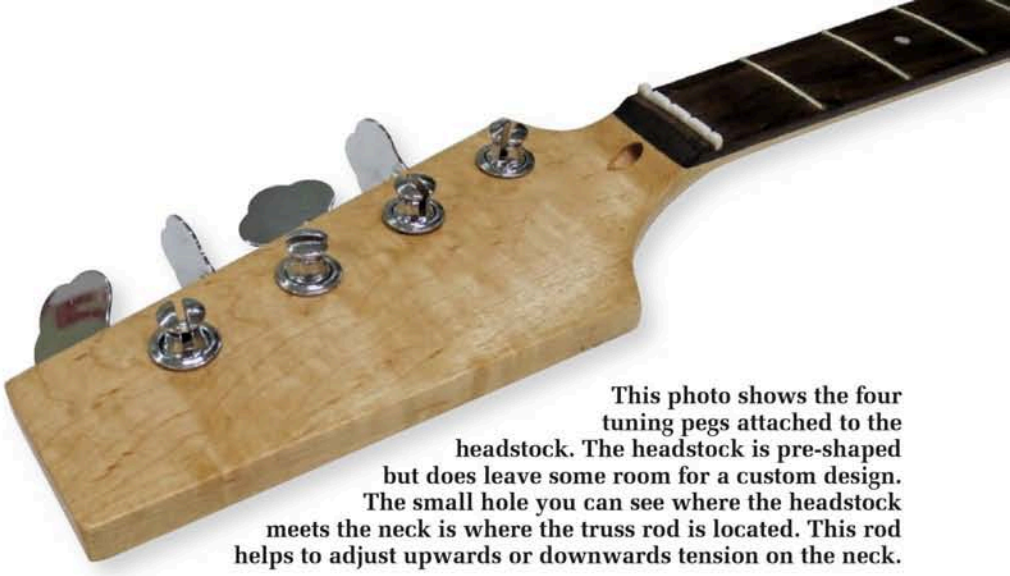
This does open a bit of a can of worms, because while lower action allows you to play faster and there is less intonation shift, it makes the guitar more prone to fretboard buzz if the neck is not quite straight or the fret heights are uneven.

As it turned out, I couldn't quite get the intonation correct on the E string because the spring around the saddle adjustment screw wouldn't let me compress it enough.

I solved that by simply cutting the spring in half! I have heard that if you use higher-gauge strings you need to move the bridge forward, but in that case, they recommend you put on a better quality bridge.

There was still a bit of an issue with the over-winding that holds the brass stopper at the end of the string fouling on the bridge saddle, but I fixed that by putting a couple of nyloc nuts on as spacers. A bit feral, but it works!

I am jumping the gun a bit here, because after fitting the bridge I needed to fit the machine heads before I could put the strings on! Lining the machine heads up is pretty easy; you just press the metal ferrules into the holes, fit the heads, line them up by eye, then mark and fit four screws for each one.



This photo shows the four tuning pegs attached to the headstock. The headstock is pre-shaped but does leave some room for a custom design. The small hole you can see where the headstock meets the neck is where the truss rod is located. This rod helps to adjust upwards or downwards tension on the neck.

Here I ran into yet another minor problem. The "reproduction" screws they supply are a bit on the cheap and nasty side, and I had the choice of either risking stripping the heads or breaking one trying to screw them into the maple neck, or drilling bigger pilot holes and risk having them work loose.

In the end I went into Bunnings and bought some much more solid-looking sheet-metal screws and drilled the pilot holes out to 2.5mm. They may not be as authentic-looking but they still look pretty good.

After that you really need to get the pickups wired in. Conveniently, the neck and bridge pickups are slightly different sizes, and the neck pickup (red wire) will only fit in the cutout closest to the neck.

The pickups are each held in place by four long wood screws, with springs fitted over the screw shaft between the pickup and the body to allow height adjustment.

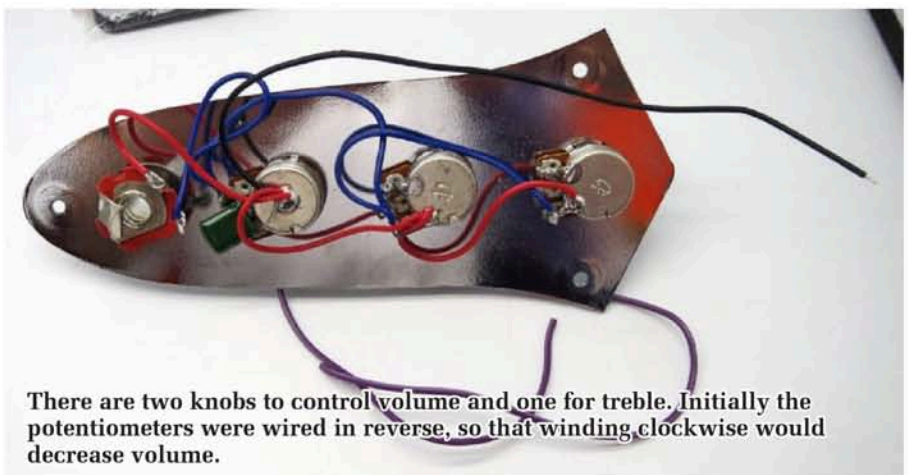
I simply fitted the pickups into position (you have to feed the shielded lead through a hole in the body first) and then used the point of a hand-held 4mm drill bit to mark where the pilot holes should go.

After that I drilled four pilot holes for each pickup with a 2mm drill. At first glance it might seem like a nightmare getting the screws and springs to stay together while wiggling the pickups into position. Actually it's no problem at all; the magnets hold everything together nicely!

The pickup wiring is pretty straightforward: the shields simply are soldered onto their appropriate pot metalwork, while the signal wires solder to the wipers of their respective pots.

This is not the usual method, but since the Jazz Bass doesn't have a pickup selector switch, wiring the pots in the conventional manner would cause interaction between the volume settings.

But then another quirk revealed itself: the pots were wired in reverse of the normal action, so fully clockwise meant minimum volume!



There are two knobs to control volume and one for treble. Initially the potentiometers were wired in reverse, so that winding clockwise would decrease volume.

It's possible that whoever designed this guitar decided that since everything else in a left-handed version is a mirror-image of the right-handed model, the pots should be wired back-to-front as well! None of my other left-handed guitars are wired like this, so I re-wired it to the conventional configuration.

Another point that needs to be addressed somewhere in the assembly process is the matter of electrical shielding of the pickup and volume control cavities.

I have my doubts that this achieves very much, given that my other guitars don't have this feature. There were suggestions about using copper foil but I simply painted the interior with "aquadag", which is the graphite-based conductive paint they put on the back of CRT TV picture tubes. Jaycar sell a very similar product called "Wire Glue", Cat NM2831.

I then ran copper wires through the access holes and fastened the wires to the conductive surface with small screws. There is also a grounding wire that sits under the bridge metalwork. You just thread the wire through an already-drilled hole, strip off some of the insulation and screw the bridge bracket onto it.

After that I fitted the supplied strings and used the truss rod to adjust the neck tension. The truss rod is adjusted with a supplied Allen key via a small hole behind the nut.

There was initially a bit of confusion as to how this adjusts, but eventually I realised that there is a half-turn "dead zone" between the clockwise and anti-clockwise directions where the rod turns with virtually no resistance, then become progressively tighter in both directions.

The truss rod I received from Pit Bull was set for zero tension, which led to the middle of my neck curving up towards the strings. This meant that the truss rod needed to be adjusted to exert force in the opposite direction until the neck was straight, such that using a straight-edge the frets will line up to the saddle.

Editor's note: it's important to note that typical fretboards for electric and acoustic guitars have a convex curvature with a radius of somewhere between 7 and 16 inches. So it's important to differentiate between the neck bending up or down, and the fretboard not being flat when doing intonation.

This is what the body of the guitar looked like after applying the first few coats of oil and wax finish.

Many guitarists find it easier to play chords and bend strings due to this curvature.

Finishing coat

Once I'd done all that and gotten the intonation and action approximately right, I turned my attention to the actual timber finish.

Instead of the usual approach of either painting or lacquering, I decided to use two products I've had great success with in the past: Feast Watson Fine Rubbing Oil and Gilly Stephenson's Cabinet Maker's Wax.

Both products are available from Bunnings and are not particularly expensive; plus they keep in their tins for years. These two products are meant to be applied to bare wood and give an old-fashioned low-sheen finish that's quite unlike any kind of painted or sprayed-on lacquer.

I've used these products for restoring a number of items of period furniture, and they are particularly useful if you're not interested in doing a full restoration (which can drastically reduce the value anyway), but simply making the wood look "presentable".

I simply strip off all the old varnish, leave all the cuts, nicks, cigarette burns etc exactly as they are, and apply the above two products with 0000 grade steel wool (also available from Bunnings).

Apart from the fact that I had some of both products already, there are a number of advantages:

1. There's no need for pre-sanding; the steel wool smooths down all the imperfections, which produces a smooth finish, while preserving the "character". But make sure to give it a quick wipe down to remove any leftover residue before applying the finish.

2. There's no real issue with the finish quickly hardening or otherwise "going off", so you can do as little or as much as you like each night, spread over several evenings.

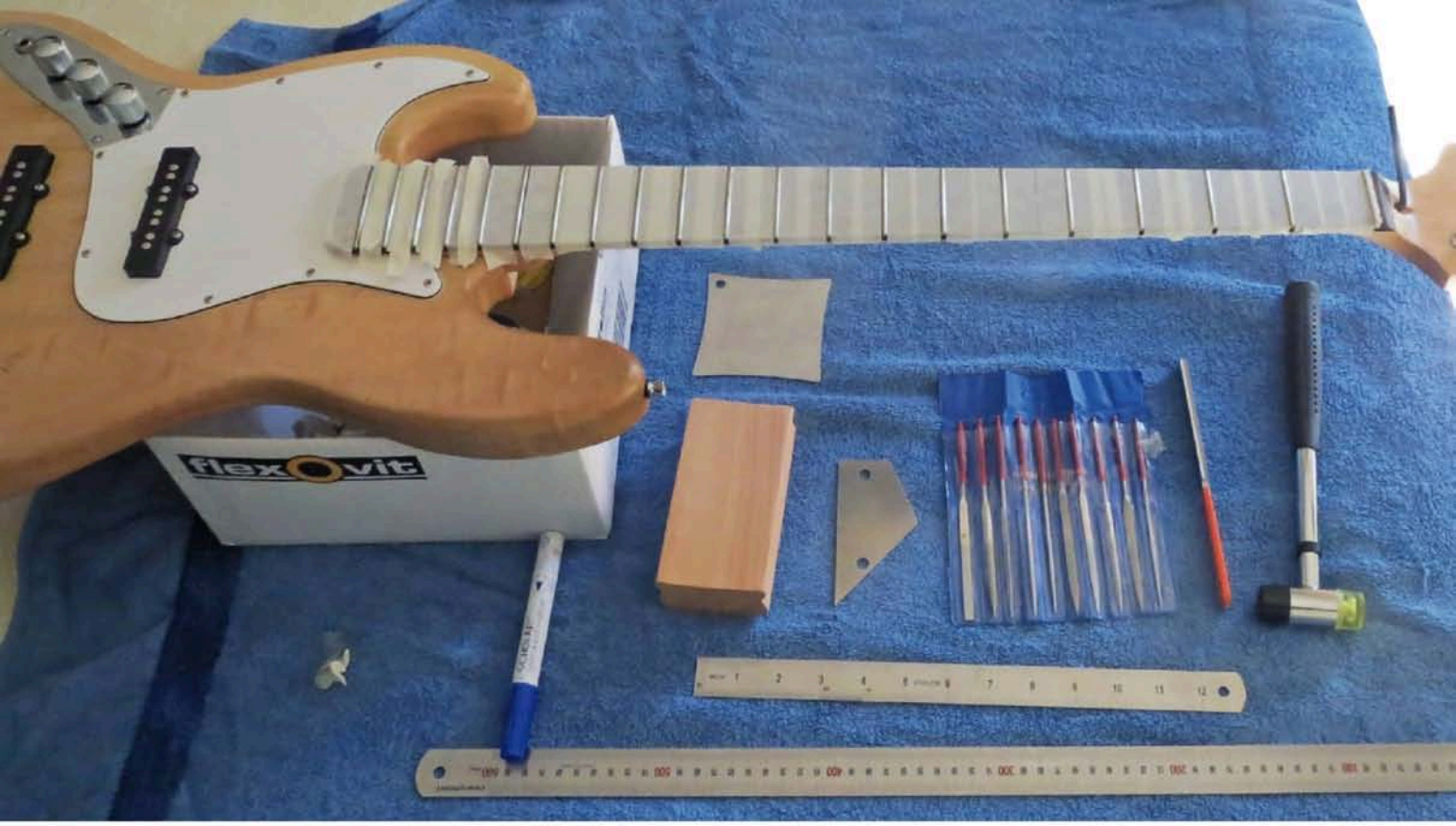
3. Both products have a pleasant gum turpentine smell; they don't smell at all "painty". You could even work on it indoors, while watching TV!

On the downside, it's a fairly slow process, and the finish takes a couple of weeks to dry completely, but the results are well worth it. The grain comes up beautifully, the finish is surprisingly durable, and best of all, if it gets damaged, it's pretty easy to repair (Pit Bull sell and recommend what sounds like a broadly similar product called "Dingotone").

If you want to do an actual paint, lacquer or shellac finish on your guitar, there is plenty of advice on how to do it on www.buildyourownguitar.com.au

However, it is far from a simple task to do properly, similar to re-painting a car. And you have to face facts. However good you are at it, you're still pretty much going to wind up with something that looks like a cheap Chinese copy bought from a music store. With the "antique" oil finish, nobody is going to know what it is!

It's worth noting that Flea of the Red Hot Chili Peppers mostly uses a custom 1961 "shell pink" Fender Jazz Bass, which appears to have had an extremely hard life. But not only is Flea clearly not interested in getting it



The guitar after applying the finish, with masking tape covering the fretboard to protect it from damage when doing fret adjustments. The tools below it are all exceedingly useful for this type of work and are as follows, from left to right: a radius gauge, 12-inch radiused sanding block, fret rocker (level-gauge type tool for measuring three frets at a time), set of diamond files, a fret-crowning file, fret hammer and rulers.

refurbished, Fender also now sell the "Flea" Jazz Bass, with all the beat-up pink paintwork faithfully replicated!

Back to building, the first step in finishing the woodwork is to remove all the metal hardware, placing the various pieces into labelled zip-lock sandwich bags with the relevant screws. I also removed the neck, but put two of the neck screws back into the neck and the other two into the body. That makes them easy to hang up between coats.

I spent about 30 minutes each evening for a week applying the rubbing oil, then another week applying the cabinet wax. The instructions are on the cans, but basically you just apply the product by rubbing it along the grain with the steel wool, give it a half-hour or so to dry a bit, then polish with a soft cloth.

You can put on as many coats as you like but after about seven you will not see much more improvement. The photo to the left shows how it looked about halfway through the procedure, which does look pretty good but I found it near impossible to take a photograph that does the actual finish full justice!

The end-grain is more problematic, because it's a lot harder to get that smoothed right down, but it still comes out looking OK; certainly no casual observer would be likely to notice.

There are various schools of thought about how the rosewood fretboard should be finished, but for my money, a single buff-up with cabinet wax is more than enough.

Editor's note: typical fretboard woods like ebony and rosewood don't necessarily need a finish due to how much natural oil they produce, compared to drier woods such as maple, but it's always something that can be done at a later time.

Headstock design

In case you're wondering about the "hatchet-like" headstock, that's how it comes from Pit Bull. For legal reasons, suppliers can't sell exact copies of name brand guitars (Fender, Gibson etc).

Apparently, it's difficult to copyright the body shape, but the headstock designs are regarded as registered trademarks. There's nothing to stop a home builder re-finishing his headstock to the standard Fender "Treble Clef" design and in fact blueprints for all popular guitar models are readily available on the internet.

But because this is being published in a magazine, I've left the headstock as is for now. I'm actually intending to make my own design anyway, and I also didn't want to run the risk of damaging something before photographing it!

On that subject, if by any chance you ever manage to hit the big-time playing your DIY guitar, you may have to consider trading up to "the real thing".

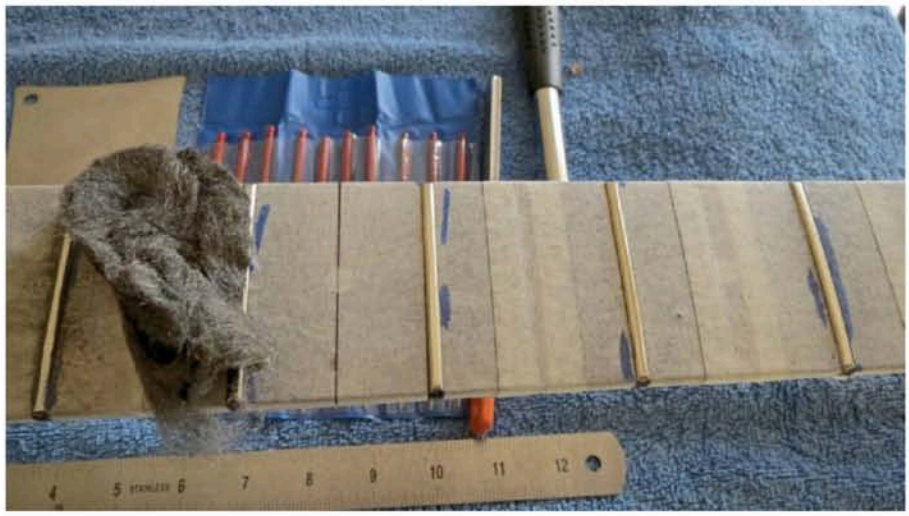
While the leading guitar manufacturers generally turn a blind eye to copies of their products being played in pubs and so on, they tend to get a bit tetchy if they start appearing in music videos and on CD covers!

Fretwork

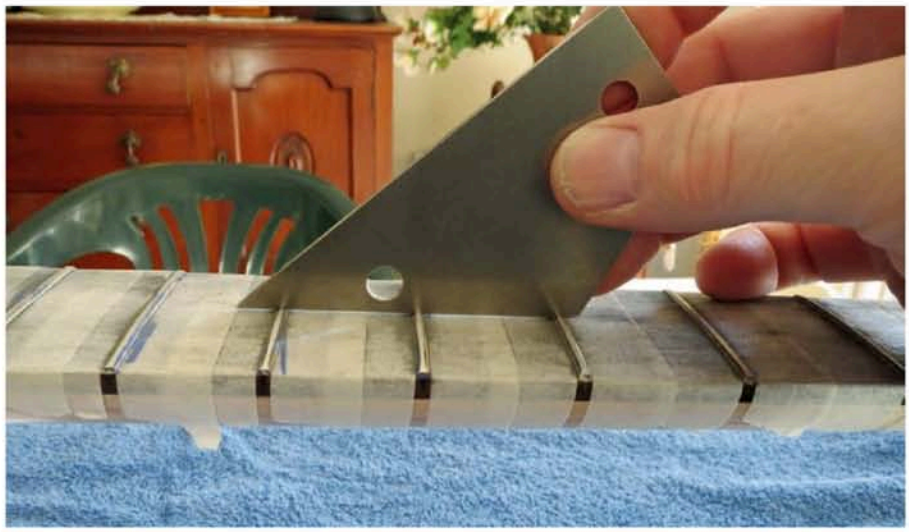
After you've gotten your guitar all assembled and prettified and so on, you should have a playable instrument, but the next thing that will need attention is the frets.

The fret heights must be carefully aligned, otherwise you will get fret buzz where the string makes contact with frets it's not meant to. This is a

Part way through shaping the frets. You can see a slight protrusion where not all of the markings have come off the crown of the frets, indicating that they are not yet all lined up.



The frets crowned and polished with 0000 grade steel wool. The profile on these frets weren't as circular as they could be, but they do the job well enough.



The fret-levelling gauge (fret rocker) being used to show that these three adjacent frets are all level.

highly specialised subject and is covered in considerable detail at **www.buildyourownguitar.com.au**

If you intend to make more than one guitar, some of the specialised (and quite expensive) luthiers' tools may be a reasonable investment, otherwise you can still get a surprising amount done with some of the more basic tools available online.

A steel ruler, a fret flatness gauge (fret rocker), a lightweight fret hammer, a basic fret file and a 12-inch radiused sanding block are the minimum requirements. A cheap set of diamond or sapphire files can be helpful too. The radiused sanding block is similar to a standard sanding block except that the side where you attach the sandpaper has been machined to match the curve of the frets in the instrument you are working on.

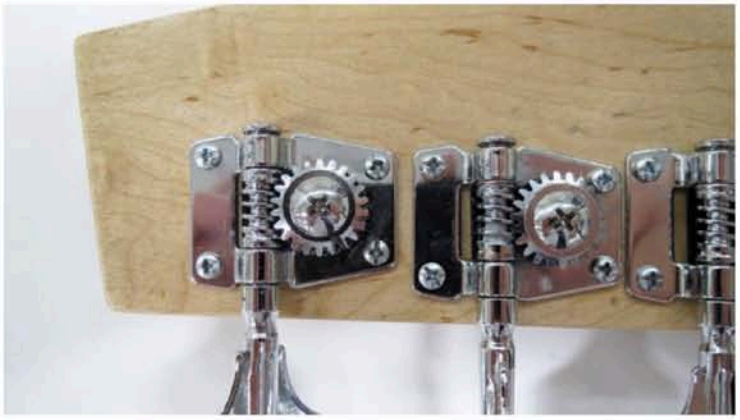
They are available in various sizes, but virtually all electric guitars use a 12-inch radius, meaning the frets match the curvature of a circle with a 12 inch (~300mm) radius. If you're not sure, you can spend a few dollars more and get a radius gauge which is the pincushion-shaped thing in the image above.

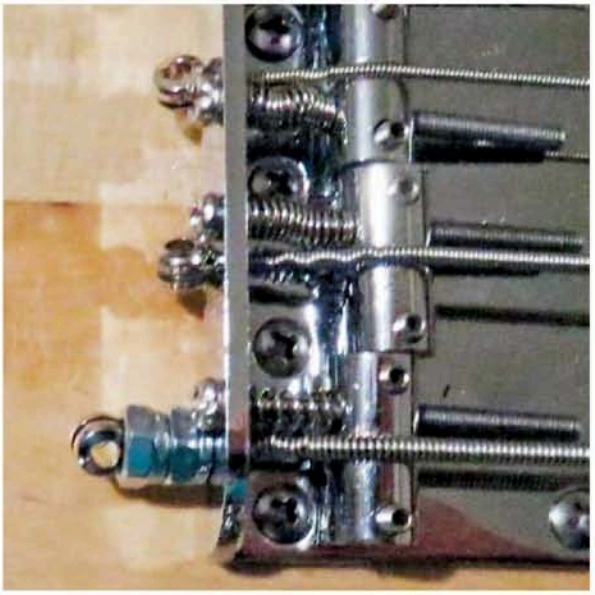
The basic procedure is to first take the strings off and get the neck as straight as you can by adjusting the neck truss rod and checking the flatness of the frets with the steel ruler.

However, before you do anything I strongly recommend you tape up the fingerboard between the frets with strips of masking tape to avoid damaging the wood and to stop steel filings from getting near it. The photo to the left shows my bass taped up and ready for adjustment, the tools laid out below it and the Allen key fitted to the truss rod adjustment.

After you've gotten the neck as straight as you can, the next step is to identify any offending frets with the fret gauge. The fret flatness gauge is simply a piece of steel plate cut with straight edges of various lengths that allow you to bridge just three frets at a time. If the middle fret of the group of three is higher than the other two, you will be able to detect this by rocking the plate.

Starting at the pickup end, identify any offending frets and then carefully and extremely slowly reduce their height until the gauge can be laid across the group of three with little or no rocking. Actually, you can





Above: a close-up of the bottom side of the chrome tuning pegs.

Right: close-up of the saddle showing adjustment springs. You can see the spring for the E-string's saddle (the lowest one) has fewer turns than the other saddles as it was cut in half to help set the intonation correctly.

start by simply tapping the offending frets down with the fret hammer. In some cases, that will be all you need, but usually you will need to use the fret file.

The fret file is actually smooth where a normal file is rough; the roughened parts are cut into the edges (it's a bit like a rat-tail file in reverse). You can get radiused fret files (crowning files) but they're horribly expensive and require considerable skill to use properly.

I must re-emphasise the "extremely slowly" part! If you overdo the filing on just one fret, you will have no option but to shave all the others down to match. Work your way along the frets, starting from the pickup end. When you reach the nut, re-check the overall straightness, re-adjust the truss rod if necessary, then repeat the entire process.

You are unlikely to get all the frets completely level this way, so once you have the frets as even as you can get them, the next step is to lightly sand the frets using the radiused sanding block and some extremely fine (800 grit or more) wet and dry sandpaper.

You can get fancy sandpaper specifically designed for this application but it's not particularly cheap and I don't see that it makes a lot of difference, although people will argue otherwise.

The first step is to mark all the frets with a felt-tip marker. That way you'll be immediately able to see which frets are being touched by the sandpaper and which are not.

After an extended period of sanding and re-marking, you should get to the point where all the frets get the ink taken off together, and at that point they are as level as you are ever likely to get them.

The very top left photo on the opposite page was taken part-way through the process. You can see how the two towards the centre have a slight "dip" which basically means the rest of the frets will have to be sanded down to match.

The final step is to carefully polish the frets with 0000 grade steel wool. This is where the masking tape comes into its own.

You can't expect to get these adjustments absolutely perfect if you're not a professional luthier with all the expensive tools, but that will by no means make the guitar unplayable. It will mostly limit how low the action can be set. It will certainly still be plenty good enough for most people!

The main difference between a full-pro job and what I've described here, is that with the pro job, the fret crowns will end up precisely semi-circular, while yours will be more trapezoid-shaped. Generally, people have rated a well-built Pit Bull kit as roughly equivalent to a $500 "store bought" job, but with vastly more "street cred"!

Setting the action

Setting the playing action is simple enough, you just adjust the screws on the saddles to raise or lower the string height off the fingerboard. Of course, as soon as you do that, the tuning will shift and will need to be re-set.

The minimum action height Fender recommend for a genuine Jazz Bass is about 2.4mm, but in practice you'd need the frets dressed by an expert for that to work without fret buzz. Setting mine to 3mm gave a satisfactorily fast playing action with zero fret buzz, and I doubt that the extra 0.5mm would make a whole lot of difference.

With a guitar tuner, setting the intonation is really quite easy (I have a modern digital one but I still prefer my 1980s vintage analog Korg for this).

You simply adjust the "E" bridge adjustment screw to the correct pitch while holding down the 12th fret, then re-adjust the open E pitch, and if necessary, adjust the bridge screw again and repeat as necessary.

With my tuner, it was easier to simply "hammer on" the 12th fret, playing it like a piano, rather than plucking the string. In most cases doing this procedure just twice per string should be enough.

Additional information

You can get more information on the process of building and setting up guitars, or purchase tools to aid you, at the following websites:

www.anzlf.com is an online Australian and New Zealand instrument maker's forum; they also have a list of local vendors.

www.stewmac.com is a fairly popular American-based luthier shop that supplies hardware, wood and everything else you could need to build primarily guitars and some other instruments.

http://luthierssupplies.com.au/ is an Australian-based business which supplies luthiery tools and supplies. SC

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

PICAXE-based Chess/Games Timer

This chess/games timer/clock provides a similar function to traditional mechanical chess clock. It forces players to make a move within a fixed amount of time which can be set from 10 to 90 seconds in 10-second increments.

Both players have a two-digit clock display showing the number of seconds remaining for their move.

Additionally, they each have an illuminated button and pressing it stops their clock and starts their opponent's clock. Player clocks run alternately, with the time counting from the set value down to zero.

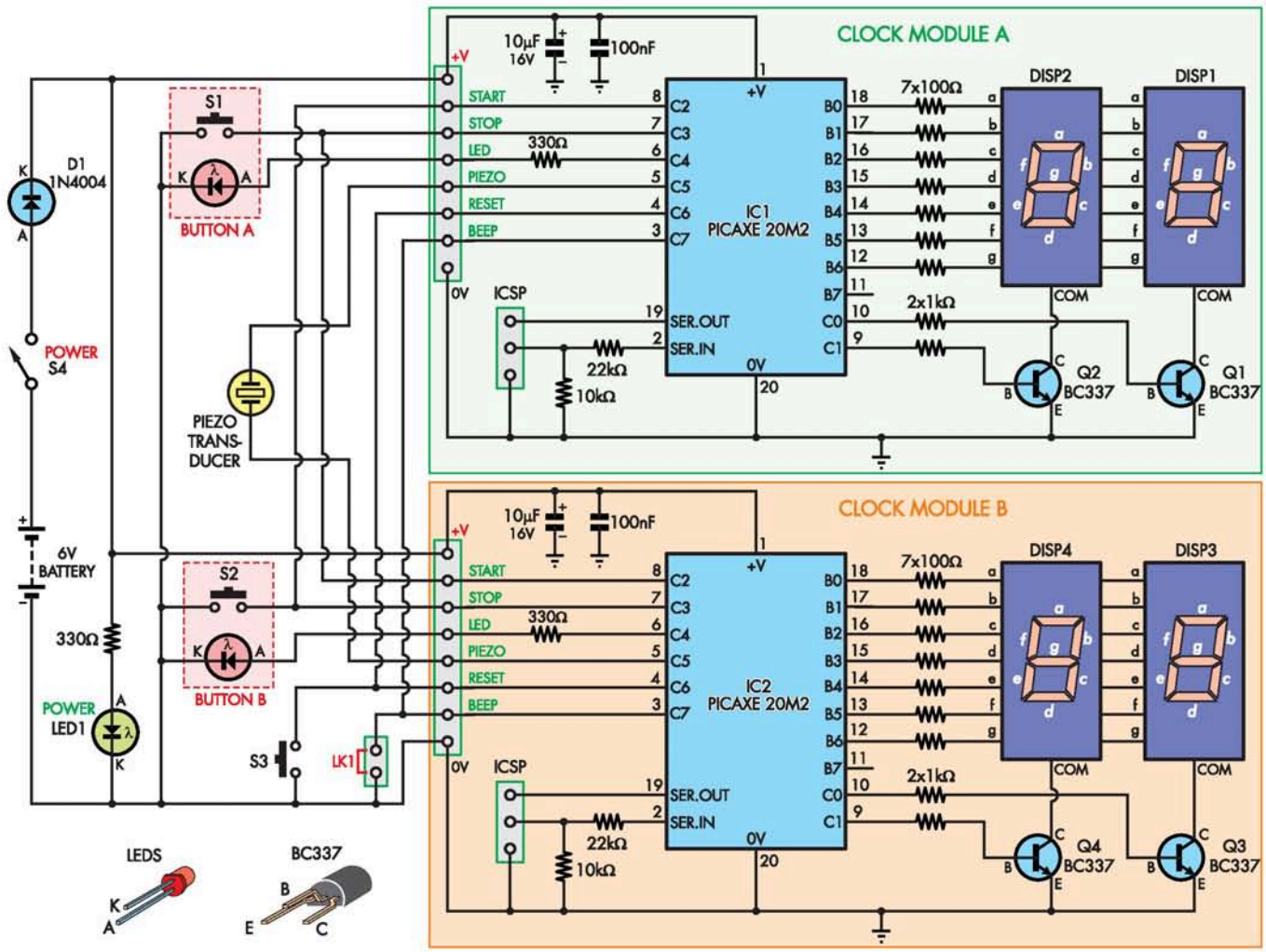
The circuit design is modular, with two identical timer modules, one for each player, and a single control panel that ties them together.

On the circuit diagram, the two identical clock module circuits are shown in boxes, with the remaining control panel components to the left. Eight-way headers connect the two clock modules together and to the control panel.

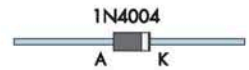
The timer modules are based around PICAXE 20M2 microcontrollers (IC1 and IC2) and each drive two 7-segment common cathode LED displays (DISP1-2 and DISP3-4).

The display anode pins are wired in parallel and driven by outputs pin 12-18 of the PICAXE via 100Ω current limiting resistors. The cathode pins are multiplexed using two BC337 transistors (Q1-Q2 and Q3-Q4).

Of the eight external connections for each clock module, two are for the power supply (+V and GND), four are inputs to the clock module (start,



SC ©2017 CHESS CLOCK USING TWO PICAXES



stop, reset and beep) and two are output outputs, one to drive the relevant player active LED and one to drive the common piezo buzzer.

All four inputs are active-low, with internal pull-ups in IC1 and IC2 to keep them high when they are not being pulled low by the control panel.

Pulling the start input low starts the timer while pulling the stop input low stops and resets it. The function of the beep input is discussed below. The common reset line is used to simultaneously reset both timers when starting a new game.

The LED output is driven high when the timer is active, lighting that player's LED. Only one timer is active at any given time during a game. The piezo output is used to drive the piezo transducer.

The transducer is connected across the piezo outputs of both clocks so that if one holds its end high or low and the other produces a square wave, it will sound a tone at that frequency.

The only other components in the timer modules apart from those mentioned above, are two power supply filter/bypass capacitors, an in-circuit programming (ICSP) header to allow the PICAXE chips to be re-flashed and a series resistor to limit current for the LED in the player button.

Turning now to the control panel at left, the switch inside each player button (S1 or S2) is wired to the start input of one timer module and the stop input of the other.

So if player A presses button A (S1), their timer stops, the other timer starts, player A's LED (in button A) switches off and player B's LED (in button B) illuminates. The opposite happens if Button B (switch S2) is pressed.

The reset button (S3) normally resets both clocks, but can also set the default move time as explained below. Fitting a jumper on LK1 pulls the beep input on both timer modules low, switching on the option for warning beeps which start three seconds before the timer reaches zero.

The remaining components are the power LED (LED1) and 330Ω current-limiting resistor, 6V battery (4 x AA or similar) to power the unit, power switch S4 and diode D1, which provides reverse battery polarity protection and also drops the voltage from 6V to around 5V to suit IC1 and IC2.

When first switched on, the default move time will load onto both clocks and they pause until a player button is pressed.

Then the active player button will illuminate and the active clock will start counting down towards zero. The player has this time to make their first move before they press the player button to stop (and reset) their clock and start the opponent's clock.

Each move must be made before the zero alarm sounds or the player will forfeit the game.

To change the default move time, hold down reset button S3 while turning the power switch S4 on. Both player clocks will count up to 90 seconds in steps of 10 and the time displayed when you release the reset button is saved in EEPROM. The new default move time will not be lost when the power is turned off.

Pressing the reset button during a game gives a master reset and the default move time will reload on both clocks and a new game starts.

The PICAXE software uses the "time" variable in BASIC to regulate the seconds count.

The device is battery powered (four AA cells, or similar), and has a power indicator (LED1) and a reverse polarity protection diode (D1) which also reduces the supply voltage to around 5V, to suit IC1. Four AA Alkaline cells give many hours of service.

The prototype was built to resemble a traditional chess clock by installing the two player clocks on the front face of the enclosure and the player controls on top.

The illuminated push buttons in the prototype were Jaycar SP0706 types while the piezo transducer device may be either a Jaycar AB3440 or the Altronics S6140. The recommended 7-segment displays are blue Jaycar ZD1856 modules.

The software for this project is named "chess_clock_20m2.bas" and is available for download from the SILICON CHIP website, free for subscribers.

To load it into the PICAXE chips, you will need a PICAXE-compatible USB programming cable and the free "program editor software" from the PICAXE website.

Ian Robertson,
Engadine, NSW. ($60)

Caravan water tank level meter tracks water usage

The water tank in my camper van came with a four-stage level sensor which often did not work properly and gave a very coarse reading of the amount of water remaining.

I recently replaced it with a new meter which uses a tilt switch to detect when the tank is full and then measures how much water is drawn from the tank, to track its level accurately. This has proven to be very reliable.

It's based on an Arduino Nano and it shows the water level percentage on a 64x128 pixel OLED display which is controlled via I^2C (see the read-out photo to the right).

When the tank is filled, the float triggers a microswitch which connects pin D5 to ground. An internal pull-up current in the Arduino keeps this input high the rest of the time and the 100nF capacitor debounces the switch contact.

So while D5 goes low, the level reading shows 100%. Then, once the switch opens, the Arduino counts pulses from the Hall-effect based flow meter.

Each pulse corresponds to a certain volume of water flowing out of the tank, so after a certain number of pulses, the level reading is reduced by 1% and this continues until either the tank is re-filled (pulling D5 low), or the tank is empty.

Once the tank is empty, switch S2 should be pressed manually. The number of pulses received from the flow meter since the tank was filled indicate

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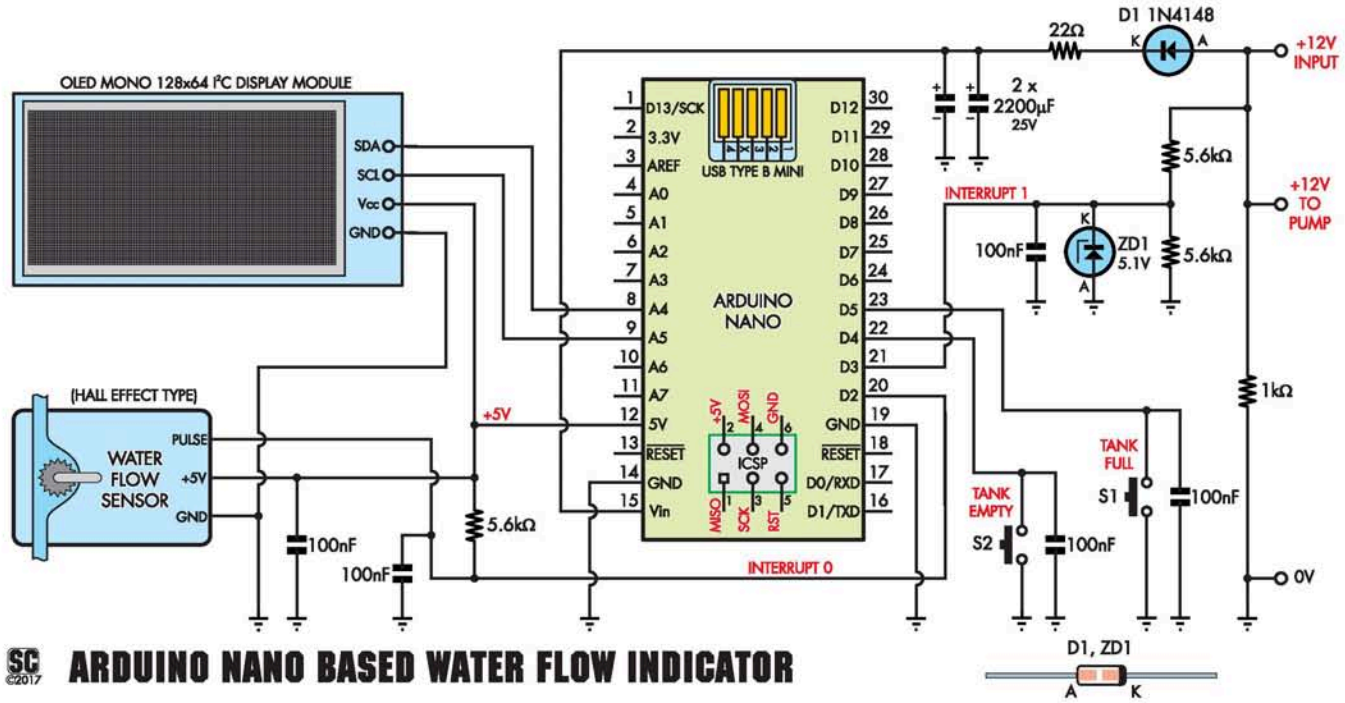

ARDUINO NANO BASED WATER FLOW INDICATOR

the full capacity and this value is then stored in EEPROM, to be used to accurately calculate the level percentage in future. This only needs to be done once.

The unit automatically switches on the OLED display when water is flowing (ie, pulses are being received from the flow meter) and switches it off after fifteen seconds of no pulses, to save power (and extend the life of the display).

If the unit loses power, it stores the current reading in EEPROM so that it can pick up where it left off when power is restored.

The pulse output from the flow meter has a 5.6kΩ pull-up resistor as it is an open-collector output. A 100nF capacitor to ground debounces the signal and this is applied to pin D2 and triggers a software interrupt on every pulse.

The 12V supply voltage is measured at input D3, which is connected to a divider across the supply with a 5.1V zener diode to protect the Arduino from over-voltage and a 100nF smoothing capacitor.

If the 12V supply drops too low, this triggers a separate interrupt in the software which saves the current tank level in EEPROM.

The two 2200µF supply bypass capacitors, along with diode D1, ensure that the Arduino will run for long enough to finish this process.

The 22Ω series resistor, in combination with the two large capacitors also serve to filter out spikes from the camper van's power supply. A 1kΩ resistor across the supply ensures it drops quickly when power is switched off.

The Arduino software sketch is named "flow_01.ino" and this is available for download from the SILICON CHIP website.

The library required to drive the OLED display, U8glib, is included in the download package as a ZIP file and must be installed prior to compiling the sketch. The only other library used is the EEPROM library, which is supplied with the Arduino IDE.

A sample PCB layout (in PDF format) is also supplied in the download package. My unit was wired up on a prototyping board.

The 1/2-inch BSP threaded flow valve was purchased on eBay. Similar devices are also available from AliExpress, for example: http://siliconchip.com.au/l/aaf6

Alfred Hirzel,
Auckland, New Zealand. ($70)

The 1/2-inch BSP threaded flow valve that was purchased on eBay.

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High power H-bridge uses discrete Mosfets

This circuit is basically a standard H-Bridge design but what makes the difference is the minimal dimension of the assembled unit, making it highly competitive with more sophisticated and expensive units, eg, the Pololu PL-758.

The Pololu unit uses all SMDs and is of a similar size to the prototype of this circuit, which is based on through-hole components.

The two types of Mosfet used are capable of handling high voltages (55V) and currents (up to 49A).

The final unit is approximately 57mm x 23mm and about 45mm high with the heatsink installed. The heatsink is cut from a Jaycar HH-8526 standard unit and is about 9.5mm wide. An insulating sheet isolates the two sets of Mosfets.

Both the power supply and the motor leads can be soldered directly onto the PCB or connected through two 2-way PCB-mounting terminals with 5mm spacing.

The circuit works as follows. The control circuitry is powered from 5V via CON1 and there are three logic-level input signals: PWR, D11 and D12.

The H-bridge outputs are disabled when the PWR input is low and enabled when it is high. When PWR is high, bringing either D11 or D12 high drives the motor in one direction or the other. If both D11 and D12 are driven low, the motor is braked.

The drive logic signals are combined using two sections of a 78LS08 quad two-input AND-gate. When output pin 3 of IC1a is high (ie, the PWR and D11 inputs are high), this switches on N-channel Mosfet Q5 directly, pulling the OUT2 pin of CON2 low.

It also switches on NPN transistor Q1, which pulls the gate of P-channel Mosfet Q2 low, also switching it on, so current can flow from the +12V terminal on CON2 to the OUT1 terminal.

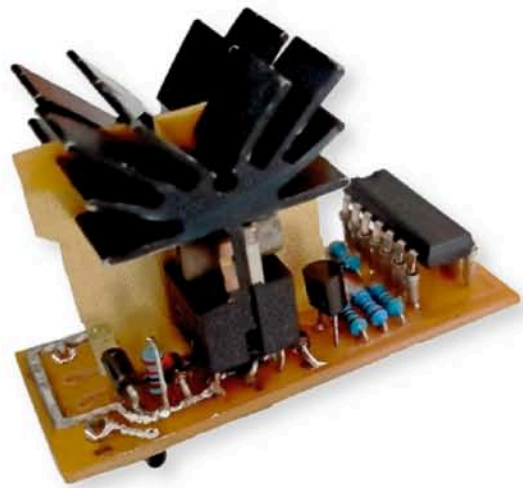
Note that there is no cross-conduction protection, so the driving circuitry must ensure that all three inputs can not go high at the same time.

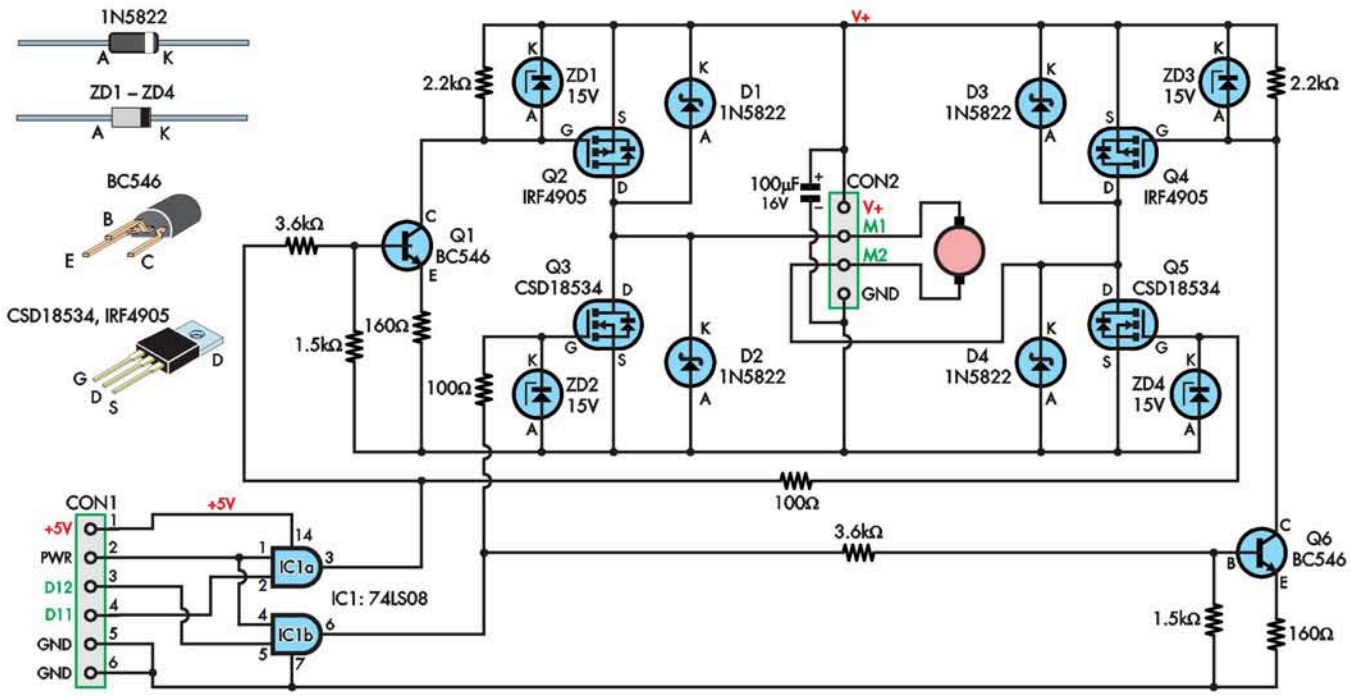
If they did, all four Mosfets would be switched on and this would short out the supply, possibly damaging the Mosfets and/or the supply itself.

It's helpful to switch one output low momentary before bringing the other high, to allow time for the two active Mosfets to switch off before the other two switch on.

Each Mosfet gate is protected from voltage spikes by a 15V zener diode and schottky flyback diodes parallel the body diodes of all four Mosfets, to quickly catch and clamp inductive spikes from the motor during switching. PDF files of the top and bottom layer PCB artwork can be downloaded from the SILICON CHIP website.

Gianni Pallotti,
North Rocks, NSW. ($50)





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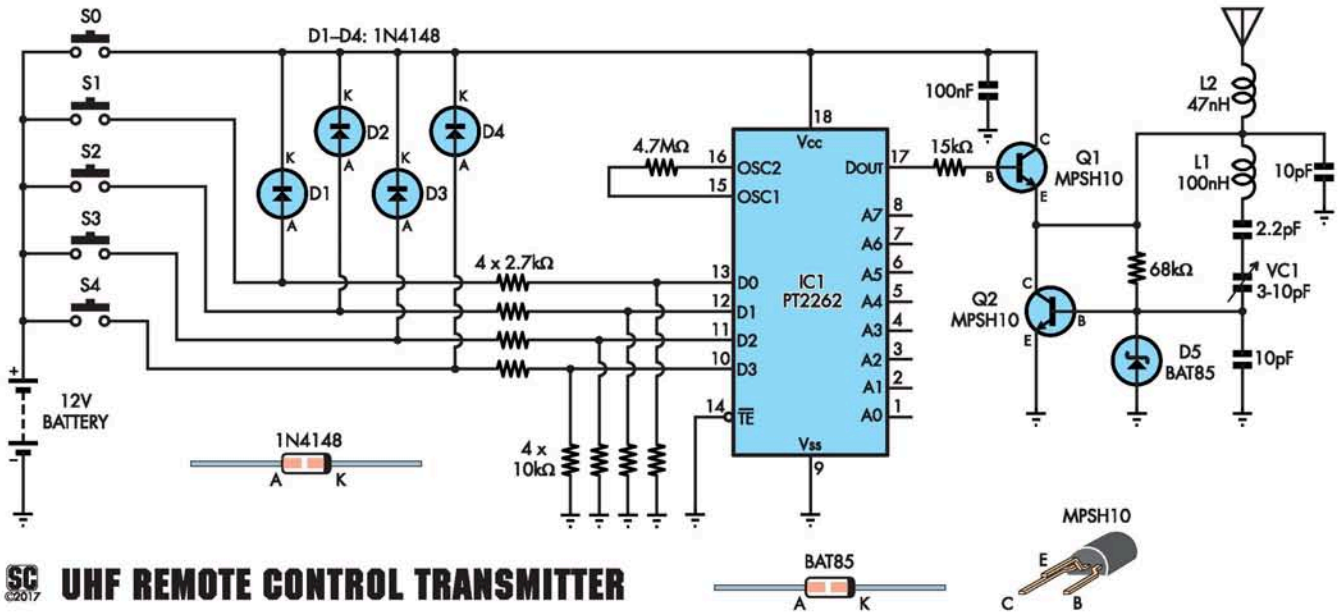


UHF REMOTE CONTROL TRANSMITTER

Four-channel RF wireless remote control has three different modes

This entry consists of two circuits. One is a four-button coded 433MHz transmitter and the other circuit is a matching receiver which incorporates a 433MHz receiver, microcontroller, LCD and four relays.

The receiver can be set up so that when a button is pressed on the transmitter, the corresponding relay on the receiver either toggles, latches on (switching the other three off) or closes momentarily, while the transmitter button is being held down.

The transmitter is based around the common PT2262 remote control encoder IC. We've had Circuit Notebook entries using this before, as part of an infrared remote.

But in this case, rather than driving an IR LED, it is driving an oscillator tuned to 433MHz which it pulses in a coded fashion, depending on the address selected and which button is being pressed.

When one of the five pushbuttons (S1-S5) is pressed, they connect the battery to the V_{CC} pin of IC1. This IC then reads the states of its D0-D3 inputs. If S1 has been pressed, D0 is high and so on. This determines which button code is transmitted by pulsing output pin 17 (D_{OUT}). Each time D_{OUT} goes high, a 433MHz radio burst is transmitted.

When D_{OUT} goes high, it drives the base of NPN transistor Q1 up to +12V. This is configured as a current-limited emitter-follower and it supplies current to the collector of NPN transistor Q2 which drives the low-distortion oscillator. A DC bias current is applied to its base by the 68kΩ resistor and the Colpitts oscillator tank is also connected between collector and base.

This comprises three capacitors (one in series with a trimmer capacitor) and one inductor. The series inductor and capacitors set the oscillating frequency while the other two capacitors provide energy storage to sustain oscillation.

This is aided by Q2, which replaces the energy in the tank circuit which is dissipated during operation, to sustain oscillation.

Diode D5 prevents Q2's base from being pulled too far below ground during negative excursions. VC1, in series with a 2.2pF capacitor, forms a variable capacitance of 1.27-1.8pF which theoretically gives an adjustment range of 412-474MHz.

This allows the oscillator frequency to be set to 433MHz for inductances of L1 in the range of 90-120nH, ie, it allows for a tolerance of -10,+20%.

Inductor L2 isolates the antenna's impedance from the oscillator as otherwise, a low-impedance antenna (such as a quarter-wave whip) would prevent Q2 from oscillating.

A quarter-wave whip antenna can be made simply by straightening and cutting a 73mm length of enamelled copper wire. A superior half-wavelength antenna would be around 146mm.

The bursts from the transmitter are picked up by a commercial 433MHz receiver module in the receiver circuit and then fed to IC1, a PT2272 remote control decoder IC which has its address pins set to the same configuration as the PT2262 in the transmitter unit.

You can change the addresses of the transmitter and receiver units by connecting any or all of the address to either V_{CC} or V_{SS}. Both units must be configured identically.

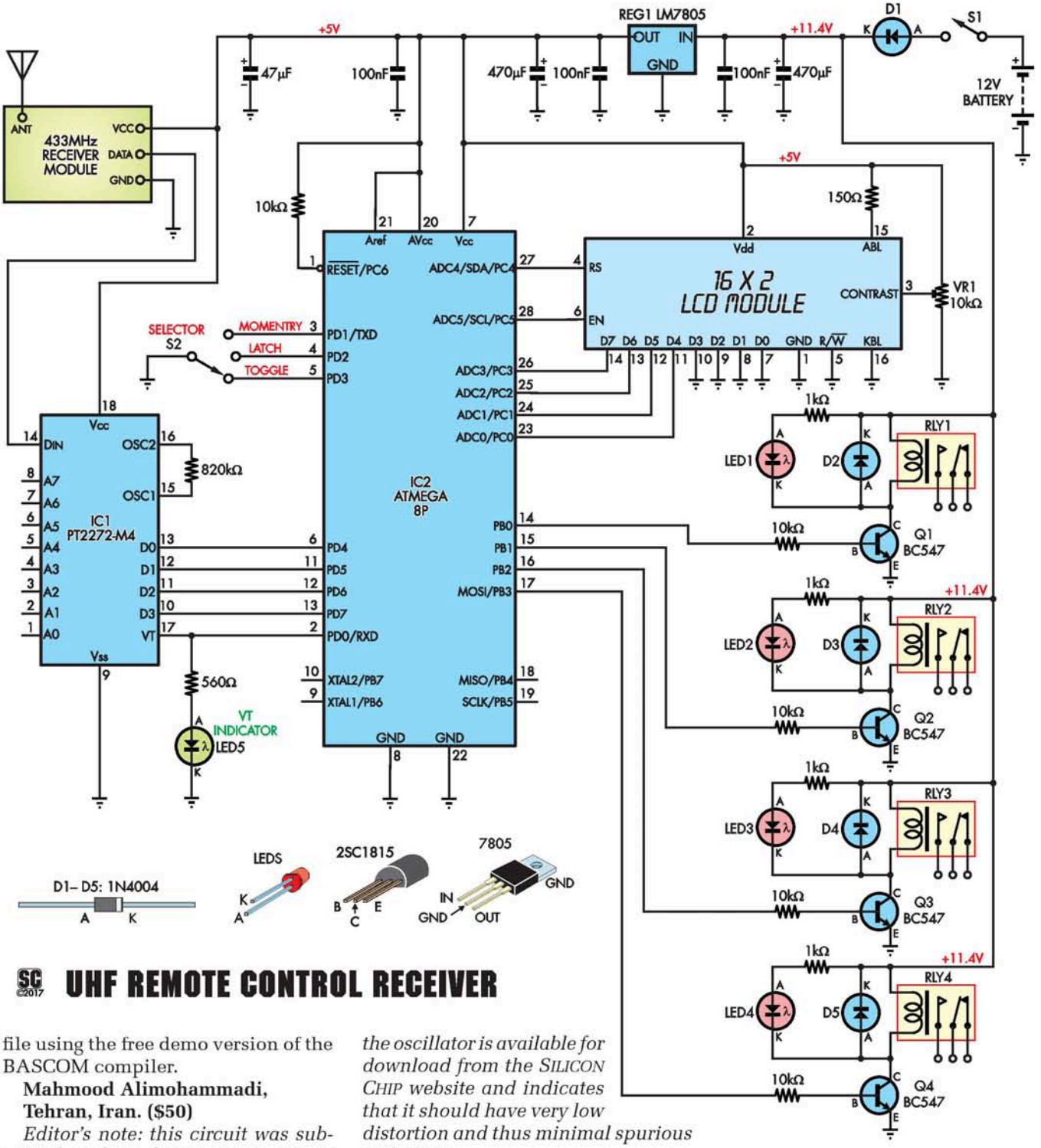
When the receiver module decodes a valid transmission, it drives one of its D0-D3 pins high and these feed digital inputs PD4-PD7 on IC2, an Atmel microcontroller. At the time same, IC1 also drives its Valid Transmission pin (pin 17) high, lighting LED5 and also pulling the PD0 digital input of IC2 high.

Depending on the position of mode selector switch S2, one of its PD1-PD3 digital inputs will also be pulled low. IC2 uses the state of these pins to decide which of digital outputs PB0-PB3 (pins 14-17) to drive high.

These in turn switch NPN transistors Q1-Q4 which controls output relays RLY1-RLY4. The status of the alphanumeric LCD is also updated to indicate the current mode and output states.

The receiver unit is also powered by a 12V battery which drives the four relay coils as well as REG1, which supplies a regulated 5V rail to the rest of the circuit.

Software for the ATmega8P in the receiver circuit was written in BASCOM and the BASIC source code (UHF Remote Switch.bas) is available for download from the SILICON CHIP website. This can be compiled to a HEX



UHF REMOTE CONTROL RECEIVER

file using the free demo version of the BASCOM compiler.

Mahmood Alimohammadi, Tehran, Iran. ($50)

Editor's note: this circuit was submitted with a design frequency of 315MHz which is not legal for unlicensed use in Australia above 50µW and this would be the case in other countries too. We have modified it to operate at 433MHz, which is legal in Australia for power levels up to 50mW.

This involved designing a new oscillator circuit which has a simulated transmit power of 12mW for antennas with a characteristic impedance of 50-150Ω. An LTspice simulation file for the oscillator is available for download from the SILICON CHIP website and indicates that it should have very low distortion and thus minimal spurious emissions.

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

6GHz+ Touchscreen Frequency & Period Counter

This new Frequency Counter has greater bandwidth and more sensitivity than any previously published design and its large touchscreen display makes using it a breeze. Now we'll describe how to assemble the two PCBs, test them, load the software and put the case together.

Part 2: by Nicholas Vinen

If you've read the first article on the Frequency Counter last month, you should have an idea of just how good its performance is and also a fairly thorough understanding of how it works.

As the photos in that issue showed, it's built using a PCB populated mainly with surface-mount devices (SMDs) plus a few RF connectors so it piggybacks onto the Explore 100, which in turn is plugged into a 5-inch full-colour touchscreen LCD panel.

We also showed the rather spiffy-looking laser-cut clear acrylic case that it's housed in on the last page of that article.

So having explained all that in detail last month, we're now going to go through the assembly procedure. It may seem a little daunting, as you have to build two separate PCBs and then assemble those two plus the pre-built LCD panel into a "sandwich" before building the box around it.

Actually, besides a couple of fine-pitch SMD ICs, most of the components are relatively easy to work with and the Explore 100 module can be put together in just a couple of hours. The Frequency Counter board may take you a little longer but it isn't too difficult and a reasonably experienced constructor can probably put it all together and get it working in one day.

Having said that – don't rush it! It's far better to take your time, especially when working with SMDs, rather than risk damaging the PCB or any components.

Even if you stuff something up, it's generally possible to remove it, clean up the board and then try again. The assembly actually lends itself to being done in stages so you may prefer to spend a couple of hours at a time on it, then stop and move onto the next stage when you're fresh.

Assembly

There are four main steps in putting together the 6GHz Touchscreen Frequency Counter. You can do the first two steps in either order: assembling and testing the Micromite Plus Explore 100 module, and assembling the Frequency Counter PCB. Once those two are finished, you can plug them together and test the unit as a whole, before assembling the case around it.

With the exception of the 5-inch LCD touchscreen, all the parts for the Explore 100 module are available as a short form kit from the SILICON CHIP Online Shop. Note though that assembling this does involve soldering the 100-pin SMD PIC32 microcontroller.

You can also get a slightly different version of the Explore 100 PCB with the SMDs, including the PIC32, pre-soldered from RicTech in New Zealand. This also comes with the other parts to fit yourself, in a similar fashion to the SILICON CHIP short form kit. See www.rictech.nz/micromite-products for details.

The circuit details of the Explore 100 module were published in the

September 2016 issue of SILICON CHIP while the construction details were given in the October 2016 issue (see siliconchip.com.au/Series/304). We won't repeat them here, however, if you don't have that issue, the process is relatively straightforward.

Briefly, you need to fit SMDs IC1 and Q1 first, being very careful to orientate them correctly and ensure that all the fillets are properly formed and no pins are shorted. Then solder the 10µF SMD capacitor in place, near IC1.

Next, install the through-hole components as shown on the PCB silkscreen printing. These consist of nine resistors, 13 ceramic capacitors, two electrolytic capacitors, three LEDs, one crystal, one transistor, one regulator, one tactile switch and numerous connectors. The LED cathodes (shorter leads) go into the holes nearest the adjacent PCB edge.

When fitting the connectors, make sure that CON6 and CON9 are fitted to the underside. You don't need to fit CON1, CON4, CON5, CON7, CON10, CON13, CON14 or the headers for the real-time clock. But if your kit comes with those parts anyway, it certainly won't hurt to install them. We do recommend that you fit JP1 as it will aid in testing.

If you haven't used a pre-programmed PIC32 then the next step is to program it using a PICkit 3 or similar in-circuit serial programming (ICSP) tool. This is done via 6-pin header CON3. Then we suggest you test the board to make sure it's working before fitting the LCD panel.

The easiest way to do this is to connect a USB/serial adaptor to CON6 and then open a terminal emulator, set to the default baud rate of 38400. Make sure the correct COM Port for your USB/serial adaptor is selected and then wire up its Tx, Rx and GND pins to the appropriate pins on CON6, making sure to wire Tx to Rx and vice versa.

To power the unit, if your USB/serial adaptor has a 5V output, you can wire this to the bottom-most terminal of JP1 (if fitted). Alternatively, fit a jumper to JP1 and plug a mini USB cable from your PC to CON2.

As soon as the unit has powered up, you should see the Micromite's banner appear on your terminal emulator. If you don't, disconnect power and recheck your wiring and COM port selection. Normal power consumption for the Explore 100 sans screen is around 100mA (at 5V). If yours is well under or over this, something is wrong, so check the PCB carefully for soldering defects and misplaced components.

Assuming you've had success, remove power and plug the LCD screen into CON10, attaching it with four 12mm tapped spacers and eight machine screws. You will then need to power it up and run the following commands on the console, to set up and test the LCD. Note that power consumption will jump to several hundred milliamps.

```
OPTION LCDPANEL SSD1963_5, LANDSCAPE, 48
OPTION TOUCH 1, 40, 39
GUI TEST LCDPANEL
```

You should now see coloured circles being drawn on the screen. Press enter in your terminal emulator to stop, then run this command to calibrate the touch sensor:

```
GUI CALIBRATE
```

You will then need to use a thin object that will not scratch the screen, like a toothpick, to carefully press and hold in the centre of the targets which appear in each corner of the screen. Hopefully, you will get a message on the console that says "Done. No errors". Otherwise, try calibrating it again. That completes the initial set-up of the Explore 100 module.

Main PCB assembly

There are many more SMDs on this board, plus a few through-hole components. Note though that the lead spacings of the components on the main board are, with one exception, much larger than those of IC1 on the Explore 100. Overall, you should find the components on this main board easier to solder.

The main board is double-sided, coded 04110171 and measures 134 x 51.5mm. Almost all components are fitted on the top side.

Start with IC4. You can use a standard soldering iron as long as the tip is not too large but we recommend that you purchase a small tube or syringe of flux paste and some solder wick if you don't already have some. Good light and a magnifier are also important.

Place a small amount of solder on one of the corner pads for IC4 and then orientate the part on the board as shown in the PCB overlay diagram, Fig.3. Pin 1 goes towards upper left – this should be indicated on the PCB silkscreen. Once the IC is orientated correctly, heat the solder you applied to the corner pad and then carefully slide the IC into place and remove the heat. This process should take no more than a few seconds.

Now carefully check that the IC pins are centred on their pads. Check all four sides. Use magnification to make sure that all pins are properly centred on their pads. If not, re-heat the solder on that one pad and gently nudge the IC towards the correct position.

Repeat this process until you are happy that the IC is correctly located and check that its pin 1 is in the correct position before tack soldering the diagonally opposite pin. Re-check that all the pins are correctly located; you can re-heat either solder joint at this point to make slight adjustments.

Now apply a thin layer of flux along all the IC pins and then apply solder to all the pins. Make sure you apply enough to get proper fillets. It's difficult to avoid bridging the pins at this point; what's most important is getting the solder to flow onto each pin and pad on the PCB.

Once all the pins have been soldered, apply another thin layer of flux paste

A couple of small errors to correct

In writing this article, we found a couple of errors in part one, published last month. Firstly, CON1 is a PCB-mounting right-angle SMA connector, not SMD connector as stated in the parts list.

Secondly, in the text at the end of page 28 and the start of page 29, it says that 32-bit timer 4/5 is used for the reference oscillator but as shown in Fig.1, it's actually timer 2/3. Similarly the previous reference to timer 2/3 in relation to the high-frequency input should have been timer 4/5.

Also, the parts list called for four 6mm M3 machine screws but we found construction a little easier using two 8mm long machine screws instead. If you can't get these, you can still use 6mm but may need to attach the spacers in a slightly different order. Or as stated in the text, 10mm screws might work.

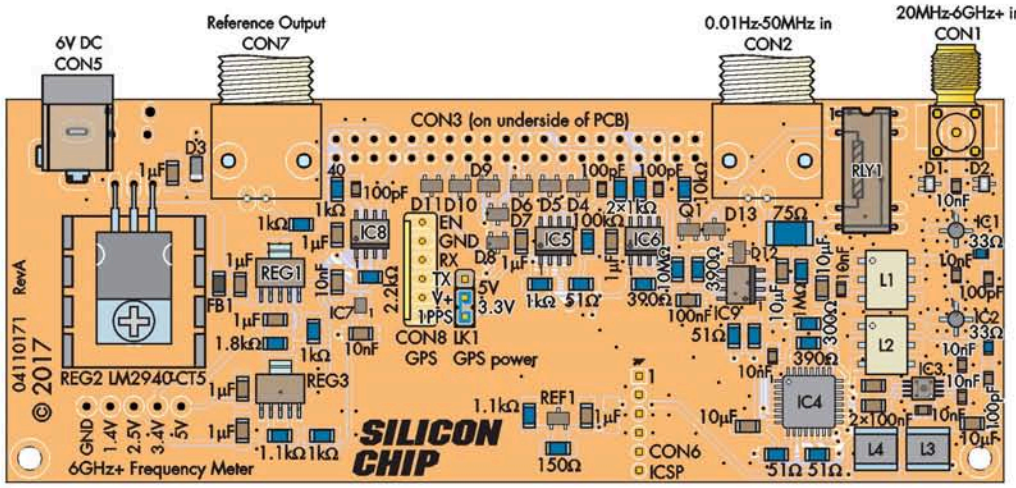


Fig.3: use this PCB overlay diagram for the main Frequency Counter board as a guide during assembly. Most of the components are SMDs with the exceptions being RLY1, REG2 and the connectors. It plugs into the Micromite Plus Explore 100 module via CON3, a 2x20-pin female header socket that's mounted on the underside of the board. CON3 and CON6 are the only components fitted to that side of the PCB.

and then use a piece of solder wick to remove any excess solder, especially where adjacent pins are bridged. Proceed carefully and re-apply flux paste if necessary.

Once you have finished, clean off the flux residue (using either a proper flux solvent or ethyl alcohol/methylated spirits and a lint-free cloth) and examine the solder joints under good light and magnification to ensure they are all good and there are no more bridges left.

When you have completed soldering IC4, you can fit IC3 in the same manner. IC3 has smaller, more closely-spaced leads but there are only eight of them, four each on two sides of the IC. One additional thing you will have to take into consideration is that IC3 has a thermal pad on the underside and ideally, this should be soldered to the matching pad on the PCB.

If you have a hot air reflow system this is quite easy, as it's just a matter of spreading some solder paste on the nine pads for this IC, putting it in position and then gently heating it until all the solder paste melts and reflows

If you are just using a regular old soldering iron, you should spread a thin layer of solder paste on the large central pad, then drop the IC down into position and tack solder it in position.

After checking that its orientation and position are correct, solder the remaining leads using the same technique as for IC4. Then flip the board over and squirt some flux paste into the hole directly under IC3.

Melt some solder into this hole and heat it for several seconds. Remove heat and carefully check that IC3 is hot by quickly touching it with your finger. This indicates that the solder has conducted enough heat through the hole to melt the solder paste you placed under it earlier.

Solder IC7 next. This is in a rather tiny 2 x 1.6mm metal can package but luckily it only has four pads, one in each corner. So soldering it is not that hard but identifying pin 1 requires significant magnification. You should be able to see a dot in one corner of the top surface and this goes to the lower-right pad.

Tin one of the pads and flux the others, then heat the tinned pad while very carefully sliding it into place. Apply a small amount of solder the other three pads, then refresh the initial one and check with a magnifier that none of the joints is shorted to the can (solder shouldn't stick easily to it).

Note that there is provision for a micro USB power socket on the underside of the board but we haven't tested this and we don't recommend you use it, for two reasons.

One, the output voltage of a USB charger is unlikely to be well-regulated and the LCD panel is quite fussy about its power quality. And two, there's the possibility of RF noise getting back into the USB cable and producing a lot of EMI.

Remaining SMDs

The rest of the parts are quite easy to install as they have more widely spaced leads. Solder IC1 and IC2 next, making sure their "pointy" pins go to the pads marked for pin 1, facing the top edge of the board. Follow with L1 and L2, both of which are in six-pin packages. Their pin 1 dot should be orientated as shown in Fig.3, towards upper left.

You can then move onto IC5, IC6, IC8 and IC9 which are all in standard 8-pin SOIC packages. These are quite easy to solder. Identify pin 1, indicated by either a dot/divot/logo in the corner or a bevelled edge on that side of the PCB. You can then orientate each IC as shown in Fig.3, tack down one pin and solder the others using a similar procedure as before.

Next on the list are regulators REG1 and REG3. These are identical parts, each with one large tab and five smaller pins. The packages have considerable thermal inertia, so spread a thin layer of flux paste on the large pad with a little extra paste on the smaller pads and drop the part in position. Then, tack solder one of the smaller pins (you can pre-tin the pad and heat it while sliding the part into place, if you like, as you did with IC3).

You can clean these joints up with some additional flux paste and an application of solder wick.

Now for the large tab. Apply some solder to this tab and hold your iron in contact with both the regulator tab and PCB pad. You may need to hold it there for some time before the whole assembly heats up enough for the solder to flow down onto the board. Keep adding solder until the tab is covered and looks shiny, then remove the heat.

Inductors L3 and L4 are similarly quite large, so again, spread flux paste on each of their pads before soldering. You can then add some solder to one of the pads and slide the inductor into place while heating that solder.

Again, you may need to wait some time before the inductor heats up enough to slide fully into place and you can then add more solder until a nice, shiny fillet has formed. Let that cool down a little, then solder the

opposite end, again waiting until it's hot enough to form a good joint (this should be quicker as both the inductor and PCB will retain significant heat).

The next components on the list are REF1, Q1 and diodes D4-D13. These are all in small 3-pin SOT-23 packages so don't get them mixed up. One of these diodes is a BAT54S (D12) while the others are all BAV99s.

In each case, tack solder one pin, check that the pins are properly aligned, solder the other two pins and then refresh the initial pin. It's easier if you spread a little flux paste on the pads before soldering each part.

Now fit diodes D1 and D2, which are in similar but slightly smaller packages than D4-D11, followed by diode D3, which is in a two-pin rectangular package. Make sure its cathode stripe faces towards REG2 (indicated with a "k" on the PCB).

You can then fit all the ceramic capacitors and resistors to the board, as well as SMD ferrite bead FB1, where shown in Fig.3. Orientation is not critical for any of these. Note that some of the ceramic capacitors are in slightly smaller 2.0 x 1.2mm packages, compared to the majority of capacitors and resistors which are in 3.2 x 1.6mm packages, but these are not much more difficult to solder.

Also, one of the resistors is a much larger 1W type but the procedure to mount this one is pretty much the same as the others. It just might take a bit more heat and flux paste.

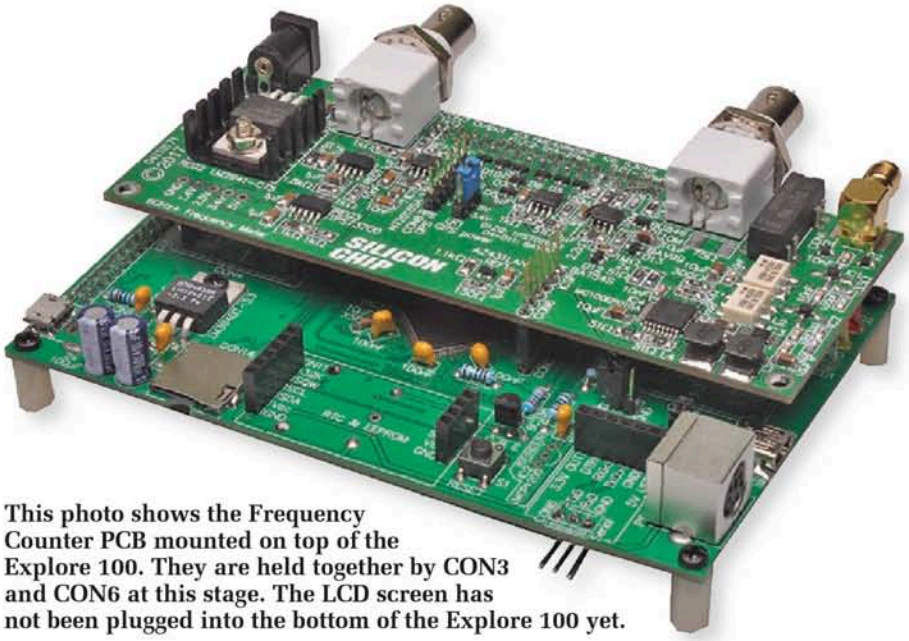
Through-hole components

With all the SMDs in place, you can now proceed to solder reed relay RLY1 in place. It's in a DIL package, like an IC but without pins in the middle section. Ensure its pin 1 indicator is towards the top of the board, as shown in Fig.3.

Next on the list is REG2 which is in a TO-220 package that's mounted flat on the board with a small flag heatsink. This is important since it needs to deliver several hundred milliamps and it can get quite hot.

Bend its leads down so they fit the pads with its mounting hole correctly located, then place the heatsink underneath and screw the whole assembly firmly to the PCB.

You can then check that the regulator's package is straight before soldering and trimming the three pins. Solder the electrolytic capacitor in next, being careful to feed the longer (+) lead through the hole marked "+" on the PCB, closest to REG2.



This photo shows the Frequency Counter PCB mounted on top of the Explore 100. They are held together by CON3 and CON6 at this stage. The LCD screen has not been plugged into the bottom of the Explore 100 yet.

The next component to fit is pin header CON3. CON3 is a 40 pin DIL socket (2x20 pins) which is mounted on the underside of the board and plugs into the Explore 100. Make sure it's pushed down fully onto the PCB and nice and straight before soldering, or else you may have trouble plugging it in later. Follow with 6-way standard pin header CON8 and link LK1, both of which go on the top side of the board.

Now mount SMA connector CON1, barrel connector CON5 and BNC sockets CON2 and CON7. In each case, ensure the part is pushed down fully onto the PCB before soldering the pins. The larger metal connectors such as CON1 require quite a bit of heat to form good solder joints.

Note that the pads for CON1 are designed to allow either a right-angle or edge-mounting ("end launch") connector. However, we recommend using a right-angle connector like we did in our prototype so that it lines up with the BNC sockets

Finally, solder CON6 in place. This is a female header socket with long pins. The socket portion goes on the underside of the board, with the pins sticking through the top (see photos). This way, it plugs into the standard header already on the Explore 100 board and allows you to reprogram the PIC32 without having to remove the Frequency Counter board. It also helps to hold them together so don't leave it off.

GPS module wiring

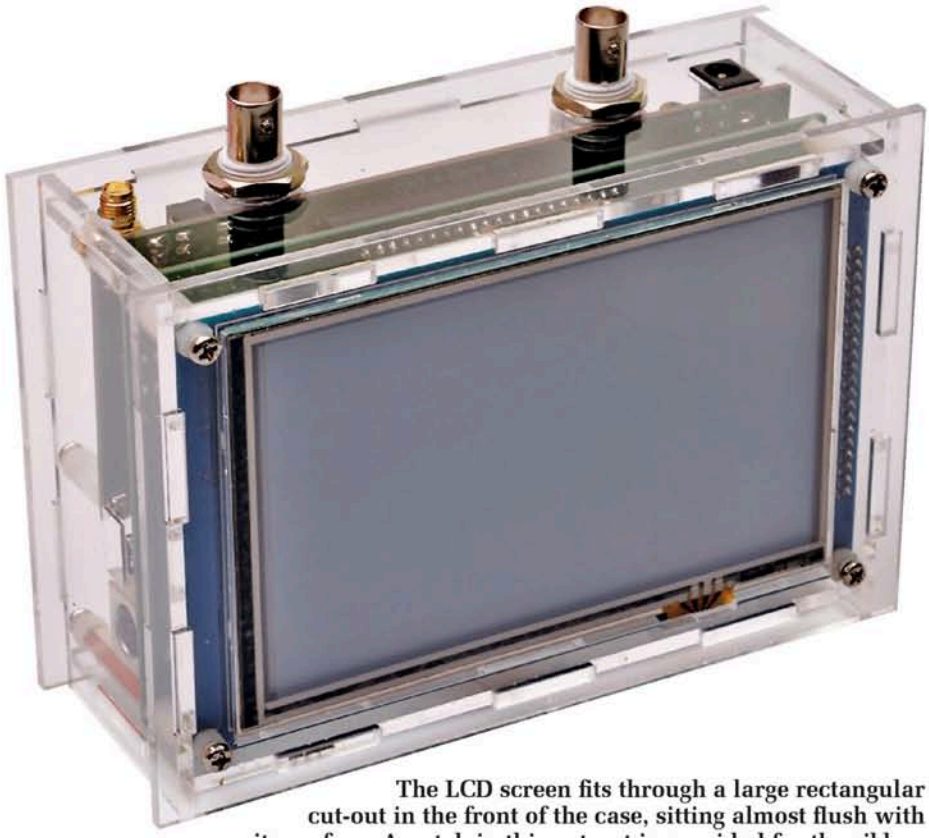
You don't need to connect a GPS module but it improves accuracy and doesn't add terribly to the cost of building the unit, so we expect most constructors will do so. If you're using the recommended VK2828U7G5LF module, it's supplied with a short six-wire cable with a small plug at one end that goes into a socket on the GPS module itself.

The wires are colour coded yellow (enable), black (ground), green (Rx), blue (Tx), red (V_{CC}) and white (1PPS). Crimp and solder these wires to the pins supplied with the 6-way polarised plug, then insert them in the same order as they are listed above.

Because the plug is polarised, you will need to ensure you start inserting them from the correct end of the plug housing. It's simply a matter of lining this housing up with the socket on the PCB, checking which end is labelled EN and then insert the pin soldered to the yellow wire into that end of the plug housing, followed by the others in sequence. Push each one in with a small screwdriver until it clicks into place.

The next step is to select the GPS module operating voltage by bridging two of the three pins on LK1 with a shorting block. For the VK2828U7G5LF, use the 3.3V setting, bridging the pins indicated on Fig.3 or the PCB silkscreen.

This actually powers the module from the 3.4V rail, which is good, since 3.3V is the minimum V_{CC} specifica-



The LCD screen fits through a large rectangular cut-out in the front of the case, sitting almost flush with its surface. A notch in this cut-out is provided for the ribbon cable at lower right. You can also clearly see how the top panel of the case is recessed to give access to the power, input and output connectors.

tion for this module and the extra 0.1V gives us a small safety margin.

If using a different module, check its data sheet. Most modules will run from either 3.3V or 5V (or both). Make sure your module uses TTL serial signalling at 9600 baud and it will need a 1PPS output to work with this project.

Also, check the data sheet to determine the pinout and route the correct wires to the plug. Some modules may not have an enable pin, or they may allow you to leave the enable pin disconnected for normal operation. The VK2828U7G5LF uses an active-high enable signal so if your module requires an active-low enable signal, you will have to wire it to GND.

You don't need to plug the GPS unit in straight away; it may be a good idea to check the unit works first, then switch off and plug it in later before checking the GPS-specific functions.

Loading the software

The recommended Explore 100 kit comes with a pre-programmed microcontroller. This is loaded with MMBasic but does not have the BASIC (and C) code required for the frequency counter loaded into it yet. Luckily, since we have already used the serial console to test the unit and set up the LCD, we can use this to load the software into the chip too.

The easiest way to do this is to download the free MMEdit software which is specifically designed to interface with Micromites. This will run on Windows or Linux machines and is available from **www.c-com.com.au/MMedit.htm**

As well as downloading and installing this program, you will also need to download the BASIC code from the SILICON CHIP website. This is free for subscribers and it's also available to those who have purchased the Frequency Counter PCB.

Extract the .BAS file and open it in MMEdit. Open the Advanced menu and make sure the "Auto crunch on load" option is selected. You then need to set up the COM port. Make sure you've closed the terminal emulator you were using before, to free up the port, then select the "New..." option in the Connect menu and select the relevant port. Set the baud rate to the default of 38,400.

You can then click on the "Load and run current code" button which is the right-most button in the toolbar at the top of the window, with an icon that looks like a blue stick figure running while holding a torch.

You should then see a progress dialog and the upload will take a minute or so. If it fails, close this window and re-check the COM port settings.

Once the upload is complete, the MMChat console window will automatically appear. Type "OPTION AUTORUN ON" into the text entry window at the top and press enter. This will cause the software to run each time power is applied.

You can then type "RUN" to start it. However, it will not work properly yet because the Frequency Counter board has not been plugged in. This will allow you to check that the software has been loaded, though.

Initial testing

Before plugging the Frequency Counter PCB into the Explore 100 (which by now you should have tested on its own), we should do some basic checks to the Frequency Counter add-on board. The first check is to measure the power consumption and check that all the supply rails are within the expected ranges. It's best to perform these checks with the GPS module initially disconnected.

The expected current drain for this board by itself is around 500mA so if you have a bench supply, set its current limit somewhere between 500mA and 1A. If you don't have a bench supply, connect a DMM set to measure amps in series with a 6V DC regulated plugpack. If that's too hard, you can simply skip this step and just check the voltages.

With power applied, connect a DMM set to measure volts between the GND and 5V test points at lower left. You should get a reading between 4.8V and 5.2V. If it's outside that range, switch off and check for faults.

A much lower reading suggests a short circuit or incorrectly orientated component somewhere on the PCB (eg, D3) while a higher reading should not be possible and suggests that REG2 has failed.

Now measure between GND and the 3.4V test point. You should get a reading between 3.3V and 3.45V. Again, a low reading would suggest a short circuit, most likely associated with IC1, IC2 or IC4 but could also be caused by a problem with REG1 or one of its associated components. A high read-

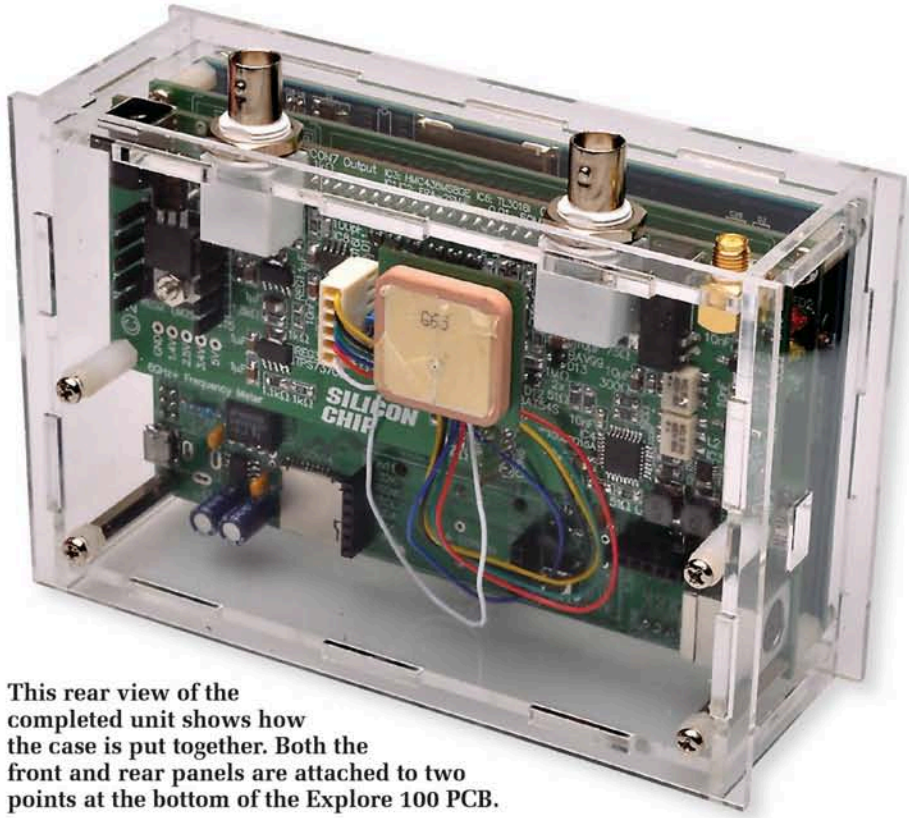
ing would suggest a fault with REG1.

The reading at the 2.5V test point should be in the range of 2.475-2.575V with a low reading likely indicating a soldering fault with IC7, the temperature-controlled crystal oscillator. A high reading would indicate a likely fault with REG3.

The measurement at the 1.4V test point should be around 1.41-1.44V with a low reading suggesting a problem with the 300Ω and 390Ω resistors located just above IC4 or one of the components surrounding REF1. A high reading suggests a fault with REF1 itself, or a soldering problem with it or one of the adjacent resistors.

Assuming that all checks out, you can power it down and plug the GPS module back in (assuming you're using one). Make sure LK1 is set properly, power the unit back up and check that the power consumption has only gone up by about 50mA and that the 5V and 3.4V rails have not dropped significantly, which would indicate a wiring problem with the module.

You can now power the PCB down and plug it into the Explore 100 board. Make sure to power the whole assembly through the DC power socket on the Frequency Meter board since the regulator on the Explore 100 is unlikely to cope with the extra current drawn by the combination.



This rear view of the completed unit shows how the case is put together. Both the front and rear panels are attached to two points at the bottom of the Explore 100 PCB.

More advanced testing

It's probably a good idea to put the unit through its paces now before it's in the case. While you can quite easily change the software once it's in the case (eg, if a bug is discovered or there's an upgrade), fixing any hardware issues would probably require you to partly disassemble the case. It wouldn't be a disaster but it's easier to test it at this stage.

The first thing to do is power it up and check that the display comes up and updates properly. Power consumption of the complete unit should be very close to 1A so verify that if you can. Then check the upper-left hand corner of the screen and make sure that you have a sensible TCXO frequency reading (close to 16.368MHz).

If you have a GPS unit fitted, you should be able to see the reflection of its status LEDs at the rear of the unit. For the VK2828U7G5LF, red indicates power and green flashes indicate satellite lock. Place the unit somewhere where it has a good view of the sky (eg, on a windowsill) and wait a few minutes.

You should see green flashes from the GPS unit and the top-right corner of the screen will update to show the

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time, date, number of satellites, your location and give a flashing green circle pulsing at 1Hz, in time with the 1pps signal from the GPS unit.

You can now connect a signal source with a known frequency to the two inputs at the left side of the unit and verify that you get sensible readings. That will verify that pretty much all the functions of the unit are working properly. We'll go into more details of the software operation next month.

Case assembly

The case is made up of six pieces of clear 3mm laser-cut acrylic, forming the front, back, top, bottom and side panels. Peel off the protective coating from each piece as you assemble the case. You will need to remove the screws from both ends of each space between the Explore 100 board and the LCD panel before you can proceed. Use Fig.4 as a guide to help you with the following assembly procedure.

Start with the front panel, which has the large cut-out for the LCD. Try to avoid bending it too much since it could potentially snap. This has a small notch for the LCD ribbon cable to fit through, so figure out which way around it goes using this notch.

Now feed a 32mm M3 machine screw through one of the two lower corner holes in the front of the panel and do up a Nylon hex nut tight, holding the screw in place. Repeat for the other lower corner. Attach 10mm machine screws to the other two (top) mounting holes in a similar manner and hold in place using Nylon nuts.

Now unplug the LCD from the Explore 100 and feed the screen through the hole on this panel, then screw the original 12mm spacers onto each screw shaft until it's holding the LCD in place firmly in all four corners. You can then plug the Explore 100 board back into the LCD panel after feeding the protruding screw shafts through its mounting holes.

Use two 8mm machine screws to attach it to the two top spacers and screw two Nylon hex nuts onto the two remaining screw shafts after placing Nylon washers under each. Do them up tightly.

Next, feed two 6mm or 8mm M3 machine screws through the two mounting holes on the main Frequency Counter board from the underside and attach them using Nylon nuts and washers, done up well.

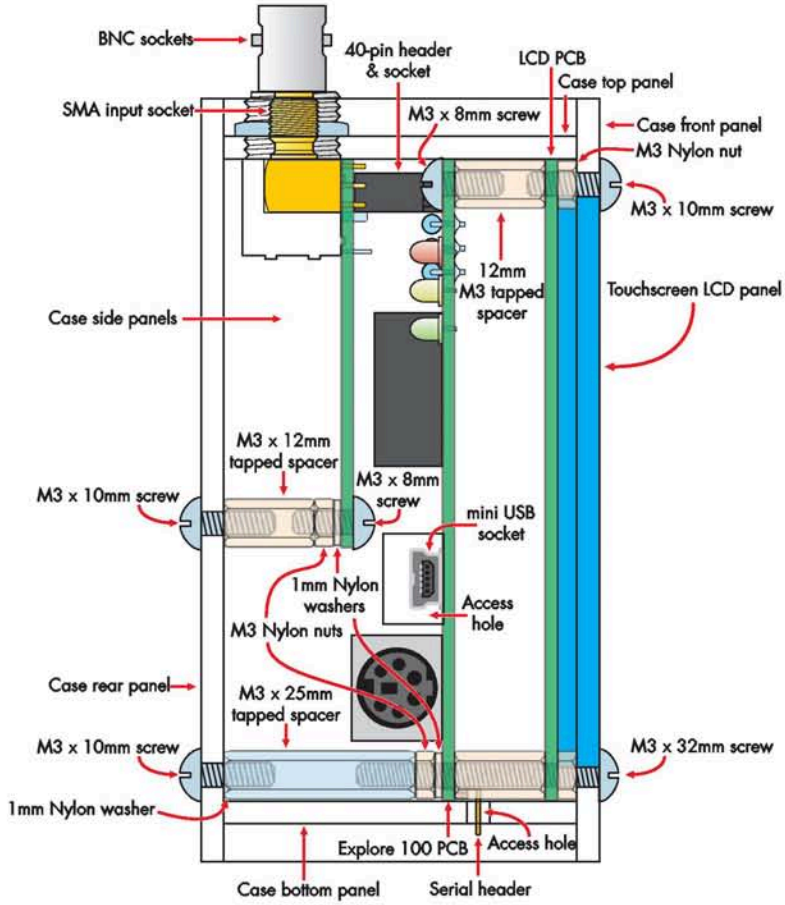

Fig.4: this diagram shows the view looking into the left-hand side of the unit and clarifies how the various screws, spacers and washers hold the case together. The side, top and bottom panels are held in place by the front and rear panels.

Note that if you can't get 8mm machine screws, you may be able to get away with 10mm screws. You can also use 6mm screws (which are also commonly available) but you may need to reverse the order of spacers in the last step.

The next step is to feed the two 25mm tapped spacers over the screw shafts in the lower part of the assembly. Once those are done up, you can place the rear panel on top of the spacers and check that the 3mm holes line up properly.

If you're wiring up the GPS module, now is a good time to attach it to the rear panel using double-sided tape and plug it into its header. There should be just enough room in the case with the rear panel fitted for the connector.

Make sure you tape the GPS receiver in a position where it won't foul any other components. We recommend that it's fitted near the top of the case for better signal reception.

Now remove the nuts and washers from the BNC connectors and then slot the tabs of the top panel into the front and rear panels. Do the BNC connector nuts back up loosely (with the washers underneath) to hold the top panel in place. The bottom panel is held in similarly, between the front and rear panels. Orientate it so that the small cut-out gives access to the serial header pins.

Now it's just a matter of slotting the left and right panels into the holes in the front and rear panels and over the tabs on the top and bottom panels. The only difference between the left and right panels is that the left panel has a cut-out to access the mini USB socket.

With all the panels in place, feed the four 10mm M3 machine screws through the holes in the rear panel and do them up loosely. Then, having checked that all panels are properly positioned, do them up properly and tighten up the BNC socket nuts.

Conclusion

That's all we have space for this month. In the next and final instalment, we will show screen grabs of the unit in operation and explain how to use it. SC

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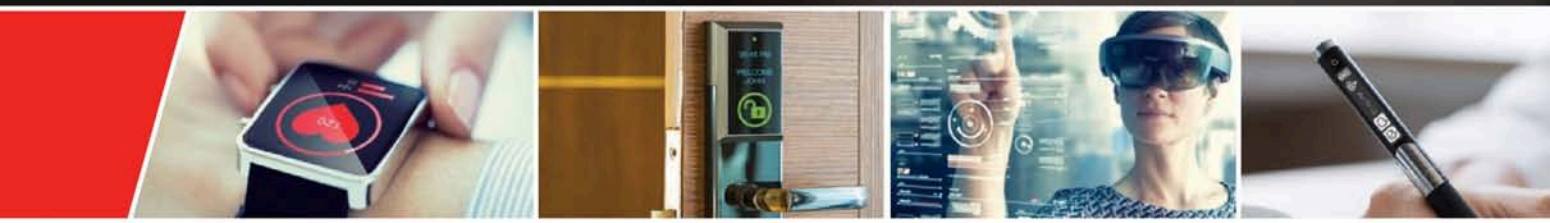

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Banggood's $30 100kHz-1.7GHz build-it yourself SDR kit

Review by JIM ROWE

This low-cost Software-defined Radio uses a standard DVT-B USB dongle to provide wide-range radio coverage from 100kHz to 1.7GHz. How do they manage it at such low cost? It turns out that they use a "direct sampling" approach which eliminates some of the circuitry which would otherwise be required. So how good is it? Read on. . .

Back in the November 2013 issue of SILICON CHIP, in an article explaining how to use our SiDRADIO SDR project to receive DRM30 broadcasts, I had a sidebar on pages 70-71 discussing the "direct sampling" approach to adapting a DVB-T dongle for MF and HF radio reception.

A number of readers had asked why we hadn't used this approach as an alternative to the up-converter approach we had used in the SiDRADIO.

In the sidebar, I tried to explain not only how a DVB-T dongle could be modified for MF and HF reception using direct sampling, but also the shortcomings of this approach with regard to reception performance, compared with the use of a preselector and an up-converter.

I concluded by suggesting that the direct sampling approach would be fine if you just wanted to use a spare DVB-T dongle for SDR reception of local AM radio signals.

But for proper reception on the LF or shortwave bands, we believe that our LF-HF Up-Converter (June 2013) or the SiDRADIO (October/November 2013) would be preferable.

The new Banggood low-cost SDR kit reviewed in this article (siliconchip.com.au/l/aag8) uses (you guessed it) the direct sampling approach for reception below 30MHz. And they've worked out a way to do this in addition to the standard no-mods-to-the-dongle VHF and UHF reception so that switching between the two bands is achieved entirely in software.

In short, they've taken advantage of the direct sampling approach to come up with a very neat little DVB-T dongle based SDR solution, in kit form and at a surprisingly low price.

It does have a few tricky aspects in terms of kit assembly and also some limitations in terms of performance. But it would still make a very good introduction to Software Defined Radio.

The assembled kit is claimed to tune from 100kHz to 1.7GHz, in two overlapping ranges: 100kHz to 30MHz using the direct sampling input and 25MHz to 1.7GHz using the regular dongle antenna input.

And it all runs from the 5V DC from a PC's USB port, which is also used for communications between the dongle and PC. In operation, it draws around 280mA.

The complete, assembled SDR is housed in a neat little metal case measuring only 83 x 50 x 20mm, finished in matte black enamel.

What you get in the kit

As shown in the photo, the kit comes with pretty well everything you'll need to build it: a very compact DVB-T dongle, a PCB for the rest of the circuitry, the parts for the metal case (including the M2 assembly screws), two edge-mounting SMA sockets for the RF input connectors, a mini USB socket and all of the minor passive components.

This includes the SMD capacitors and resistors, three small electrolytic capacitors and two LEDs. There's also a tiny ferrite toroid (5mm outer diameter) for winding the coupling balun, plus a length of very fine (0.06mm

The Banggood SDR kit comes with everything needed to build it. However, you may find an external and/or active antenna improves its performance.

outer diameter) enamelled copper wire to wind it. There's also a length of 0.5mm outer diameter enamelled copper wire to wind the two small low-pass filter coils.

You also get a 1m USB cable to hook up the finished SDR to your PC, plus a 250mm-long loaded whip antenna with a 2.9m cable fitted with an SMA plug for connecting it to either of the SDR input sockets.

You can download a 7-page PDF from the Banggood website which includes the kit assembly instructions. The text is a bit sketchy in places and doesn't explain some things particularly well but there are quite a few photos which help clarify things.

The kit comes with one spare component for each of the SMD capacitors and resistors, in case one of any of these tiny parts is lost. There's also one additional M2 screw along with the eight needed to assemble the SDR case. Very helpful!

One thing you don't get, though, is the software needed to run the SDR on your PC. For this, you need to download an SDR application like SDR# (available from www.airspy.com).

If you haven't played with dongle-based SDR before it's also a good idea to go to the RTL-SDR website (www.rtl-sdr.com) and download their Quick Start Guide file, which explains a lot about installing SDR# and the drivers it needs in order to communicate with a dongle-based SDR.

We published an article which explained the process of setting up SDR# starting on page 12 of the May 2013 issue. We have also reproduced the series of steps required to install SDR# in a panel in this article and even if you're referring to the May 2013 article, you should read that as some things have changed slightly to suit newer versions of Windows.

A quick look at the circuit

Just before we discuss assembling the kit, take a look at the circuit diagram, Fig.1. This is much clearer and easier to follow than the one included in the instructions from Banggood.

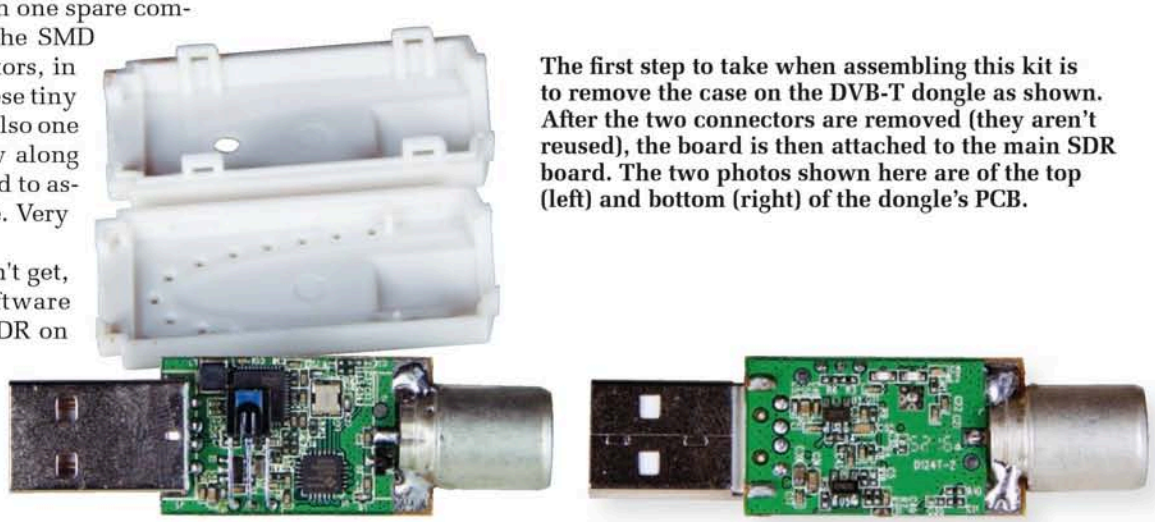
The circuitry of the dongle itself is shown in simplified form inside the light green filled rectangular area in the centre. As you can see, it uses two main chips: a Rafael Micro R820T VHF-UHF tuner chip and the Realtek RTL2832U digital demodulator chip with its inbuilt USB interface. The latter is really the heart of the dongle and also that of the overall SDR.

Notice that by using a dongle with the R820T tuner chip ahead of the RTL2832U, Banggood's designers have made it easier to use the direct sampling approach. That's because the R820T has only one pair of differential outputs, rather than the two pairs used by other popular tuner chips like the Elonics E4000 or the Fitipower FC0013.

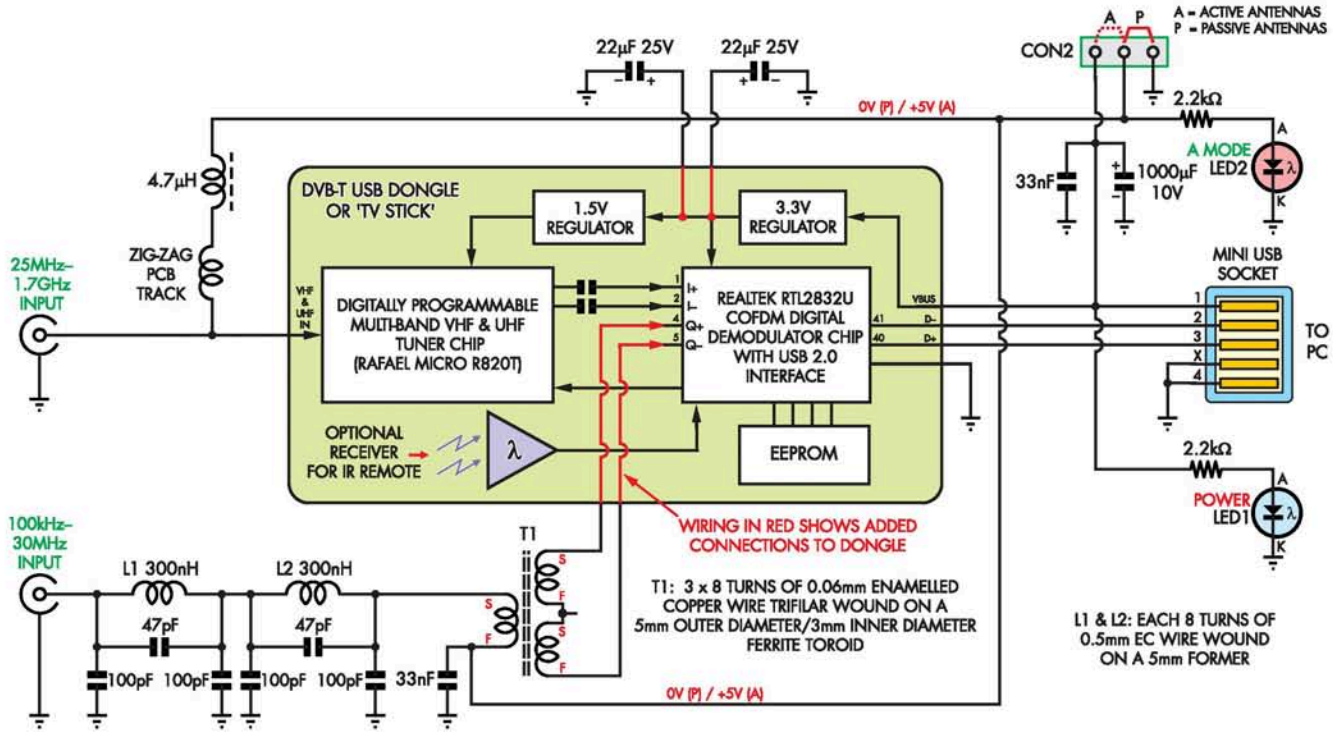
Since the outputs from the R820T only use the I+ and I- inputs of the RTL2832U, this leaves its Q+ and Q- inputs free for feeding in the LF-HF input signals for direct sampling.

The components and wiring outside the green rectangle in Fig.1 is the additional circuitry used in the Banggood SDR kit, to extend its frequency range downwards to 100kHz and also to improve its performance and flexibility.

The circuitry at lower left is used for direct sampling of lower frequencies, and as you can see is fairly straightforward. The signals first pass through a two-stage low pass filter comprising coils L1 and L2 plus their associated capacitors; then balun transformer T1



The first step to take when assembling this kit is to remove the case on the DVB-T dongle as shown. After the two connectors are removed (they aren't reused), the board is then attached to the main SDR board. The two photos shown here are of the top (left) and bottom (right) of the dongle's PCB.



SC ©2017 BANGGOOD SOFTWARE-DEFINED RADIO

Fig.1: the heart of this software-defined radio (SDR) is the DVB-T dongle shown in the centre, it uses a multi-band tuner chip and the Realtek RTL2832U COFDM digital demodulator chip which also provides the USB interface.

is used to change them into differential form to feed into the Q+ and Q- inputs of the RTL2832U.

Finally, note that the kit designers have also made provision for both of the SDR inputs to be provided with 5V DC "phantom" power, by using the A setting of link header CON2 (at upper right). This makes it easy to use active antennas with the SDR, or to use a preselector with gain in the case of the direct sampling LF-HF input. It's a nice feature which doesn't seem to be explained in the Assembly Instructions.

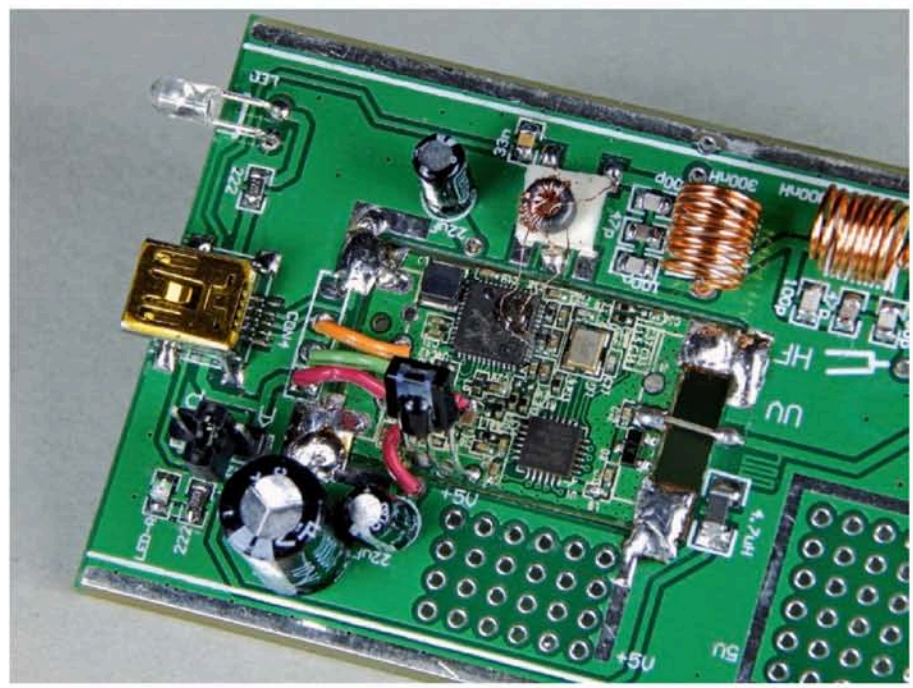
Assembling the kit

The first step in building the kit is to prise open the DVB-T dongle's plastic case to reveal the tiny PCB assembly; the PCB itself measures only 28 x 17mm and is shown on the preceding page. The next steps are to remove the USB type A plug from one end of the PCB and the Belling-Lee RF socket from the other end.

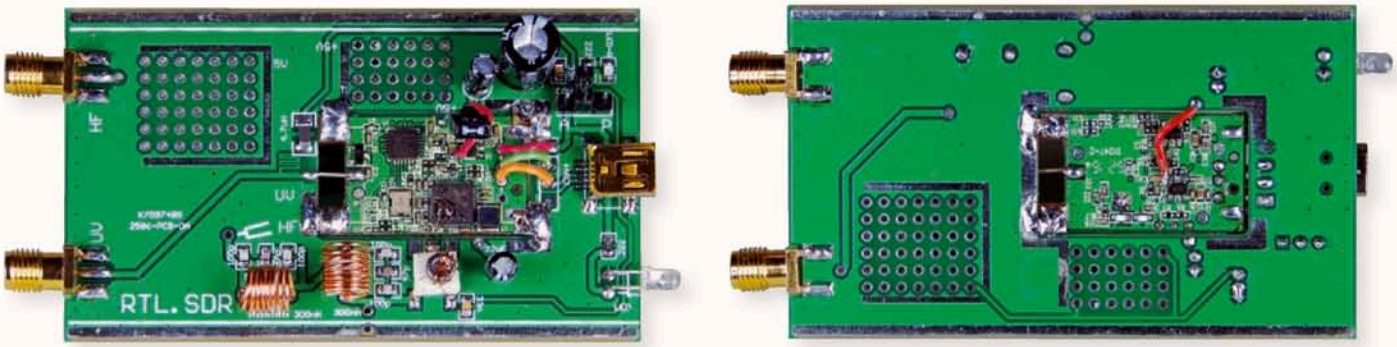
These steps turn out to be a little tricky because you have to do them with a fairly high-powered soldering iron while at the same time being careful not to damage the many tiny SMD components already fitted to both sides of the PCB.

To make things easier for myself, I first used a jeweller's saw to cut off both connectors level with the ends of the PCB, leaving only their inner portions to be desoldered and removed.

Once the connectors have been removed and their holes in the PCB cleaned up, it is ready to be fitted inside the main SDR PCB, in the rectangular cut-out in the centre. But before you do so, it's a good idea to fit most of the other components to the main PCB.



A close-up of the assembled PCB showing the various connections required between it and the dongle. The most important thing of note is the connection from toroidal transformer T1 to pins 4 & 5 of the RTL2832U micro.



The photos above show the top (left) and bottom (right) of the completed SDR board. There are a reasonable number of through-hole and SMD components that need to be soldered to the board along with securing the dongle PCB in the cut-out. It's best to solder many of the smaller components to the board before attaching the dongle PCB as there isn't a lot of space to work with.

I added the SMD capacitors and resistors first, followed by the 4.7µH SMD inductor and SMD LED2. By the way, these are all 0805 parts (2.0 x 1.2mm), so you need a soldering iron with a fine and well-tinned tip.

Next, I fitted the two edge-mounted SMA sockets at the input end, followed by the SMD mini USB connector at the output end. Then I decided to solder the dongle PCB in place.

This needs to be done carefully; it's attached to the main PCB using short lengths of 1mm diameter tinned copper wire or tiny pieces (3 x 4mm) of thin brass shim, soldered to each corner of the smaller PCB.

I found the easiest way to do this was to first solder these pieces to the ground copper on each corner of the top of the dongle PCB.

Then I could lower the assembly into the main board cutout, so the added pieces held it in place while I soldered the outer ends of each to the earth copper on the top of the main PCB. The kit designers have left these areas unmasked and pre-tinned.

Next came the really tricky steps: first winding the tiny balun transformer T1, then fitting it to the main PCB in the location shown and finally soldering the ends of its outer secondary wires to pins 4 (Q+) and 5 (Q-) of the RTL2832U demodulator chip on the dongle PCB.

Winding T1 isn't too hard but because it's wound as a trifilar (three wires at once) coil using very fine wire (0.063mm diameter) on a very tiny (5mm OD, 3mm ID) toroidal ferrite core, it ain't easy either.

You first need to straighten the wire, then fold it into three, twist together and then thread the twisted wire trio through and around the miniature toroid eight times.

Then you need to cut them apart at each end and use a multimeter or DMM to carefully identify the start and finish of each wire.

One of the wires becomes the transformer's primary, with its ends cut short and soldered to the pads between T1 and the board edge after you have attached T1 to the main PCB using a 5 x 6mm piece of double-sided adhesive tape.

The start of one of the remaining wires is then twisted together with the finish of the other wire and after cutting them short, they are then soldered to the centre pad between T1 and the dongle PCB.

The really tricky step is soldering the two remaining wire ends to pins 4 and 5 of the RTL2832U chip.

This is because the wire is extremely fine; the pins of the chip are spaced less than 0.4mm apart and there are tiny SMD components mounted on the top of the dongle PCB only about 1mm away from the body of the RTL2832, very close to pins 4 and 5. See the close-up photo of the finished job directly left.

Frankly, I found soldering these wires to the chip pins very difficult, even using a binocular microscope and soldering iron with a very slim tip. I ended up having to use a drop of epoxy cement (Araldite) to hold the ends of the wires in position over pins 4 and 5.

Then when the cement had cured, I was finally able to solder them to the pins without any solder bridges.

Once these steps had been done (whew!), assembling the rest of the kit was fairly straightforward. Completing the board assembly was mainly a matter of fitting the three small RB electrolytic caps plus the blue power LED and six additional wires making the connections between the two PCBs.

Five of these wires go on the top, with one of them being a short length of 0.8mm diameter tinned copper wire connecting the input of the dongle PCB to the track on the main PCB coming from the VHF-UHF input connector (labelled "UV", for some reason).

Three of the others are 7mm lengths of insulated hookup wire making the power and USB connections at the other end of the dongle PCB.

The remaining wire is another 7mm length of insulated wire, used to connect one of the 22µF electrolytics (near the 1000µF electro) to the output pin of 3.3V regulator U2, at the end nearest the RTL2832U.

The final wire goes under the PCB assembly, being a 14mm length of insulated wire used to connect the other 22µF capacitor on the main board in parallel with the SMD capacitor C52 on the dongle PCB (see photo at upper right).

The very last components to fit on the main PCB are the two hand-wound low pass filter coils L1 and L2. These are each wound from the 0.5mm enamelled copper wire, with eight turns wound on a 5mm diameter former like the shank of a 5mm drill bit. Then the wire ends are bent out radially and tinned, to allow them to be soldered to the pads provided to the left of T1 (see photo at left above).

Once these final components and wires have been fitted, the SDR board assembly is essentially complete and ready to be fitted into the lower part of the case.

This is done by sliding it into one of the channels in the sides until the SMA input sockets are protruding out at the far end. Then you attach that end

Installing SDR# and the required drivers on your PC

If you are using our instructions for installing SDR# from the May 2013 issue, please note that we published a follow-up on page 82 of the November 2013 issue. This points out that you may need to install the latest Microsoft .NET framework before you can install SDR# (SDR# since 2015 has required .NET 4.6 minimum to run). Having said that, most modern Windows machines (ie, Windows 7/8/10) should already have the .NET framework installed.

Also, the latest versions of SDR# will not run on Windows XP. XP is no longer supported and its users should upgrade to a newer version to avoid security problems. Similarly, while it will likely run on Vista, the operating system is no longer supported.

The other package that you may need on your system is the Visual C++ Runtime. The download locations for both packages are listed in the steps below.

The steps to install SDR# on a Windows PC are as follows (based on the RTL-SDR quick start guide):

1) Install the Microsoft .NET 4.6 redistributable, available from www.microsoft.com/en-us/download/details.aspx?id=48130 This is not required if it's already on your PC, which should typically be the case for Windows 10 users.
2) Install the Microsoft Visual C++ Runtime redistributable, available from www.microsoft.com/en-us/download/details.aspx?id=8328 Again, this is not necessary if you already have it; the installer should tell you if you are not sure.
3) Click on the downloads button at the top of www.airspy.com and download the x86 version of sdrsharp.zip, next to the heading titled "SDR Software Package".
4) Unzip the contents of sdrsharp.zip but don't run anything yet.
5) Double click install-rtlsdr.bat within the extracted files. This should download the files "rtlsdr.dll" and "zadig.exe" into the same directory (you may need to run this batch file as an administrator).
6) Plug in the dongle and wait for Windows to attempt to install the drivers (it will likely fail).
7) Right-click zadig.exe and select "Run as administrator".
8) Make sure "List All Devices" is checked in the Options menu.
9) Makes sure either "Bulk-In, Interface (Interface)", "RTL2832UHIDIR" or "RTL2832U" is selected in the drop-down list.
10) Ensure that WinUSB is selected in the box to the right of the green arrow.
11) Click the Replace Driver button. You may get a warning that the publisher cannot be verified; if so, select "Install this driver software anyway". Note that you may need to run zadig.exe again if you move the dongle to another USB port.
12) Open SDRSharp.exe. Note that the first time you do this, you may get a message indicating that Windows has protected your PC. This is a false alarm, so click on "more info" and then "run anyway".
13) Set the drop-down box in the "Source" tab at upper left to "RTL-SDR (USB)".
14) Press the Play button.
15) Press the Configure button (looks like a gear) up the top, next to the Play button. By default, the RF gain is set at zero, so adjust it upwards until you start seeing the expected RF signals being picked up in the SDR display.

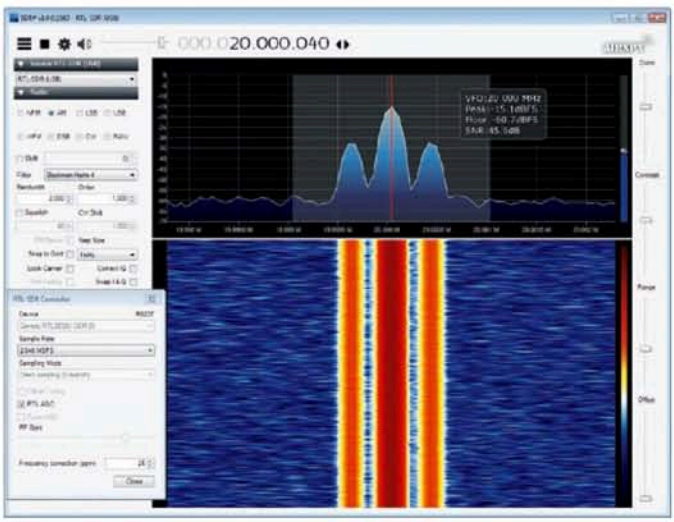
That's it, your SDR# software is ready to go.

plate, with the sockets passing through the matching holes.

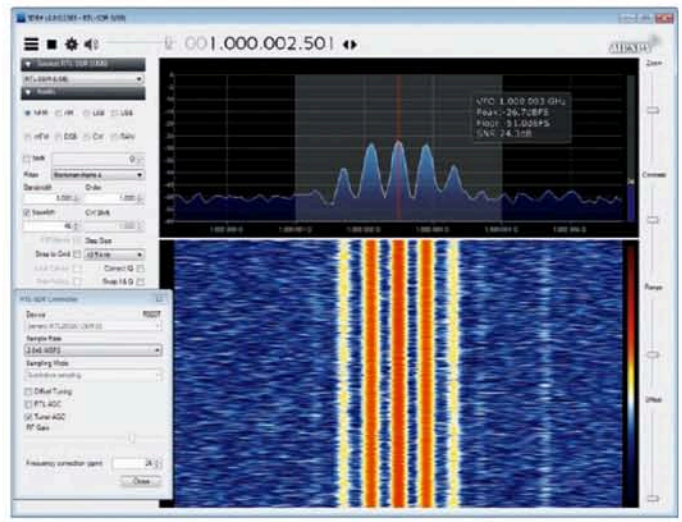
After this, the front plate can be secured to the lower half of the case using two of the M2 screws.

The rear plate is fitted in the same way, after bending the leads of power LED1 so its body lines up with the matching 3mm hole. The mini USB socket will also protrude slightly through its matching hole.

All that remains is to attach the top half of the case, which simply involves lowering it into place (with the correct orientation, since the two halves



224µV 20MHz AM test waveform in SDR#.



5µV 1GHz NFM signal in SDR#.

BANGGOOD SDR PERFORMANCE ON THE VHF-UHF RANGE (5µV NFM signal)			
Frequency (MHz)	Carrier Peak (dBFS)	Noise Floor (dBFS)	Signal/Noise Ratio (dB)
30.1	-23.2	-50.4	27.2
110.1	-18.1	-48.3	30.3
150.0	-4.4	-42.7	38.2
500.0	-15.6	-46.4	30.5
800.0	-22.0	-47.1	25.1
1000.0	-26.7	-51.0	24.3
1200.0	-31.1	-48.7	17.7
1400.0	-34.6	-55.7	21.1
1500.0	-36.4	-53.0	16.6

TABLE 1 NOTE: dBFS = dB relative to full scale

BANGGOOD SDR PERFORMANCE ON THE LF-HF RANGE (224µV 30% AM signal)			
Frequency (MHz)	Carrier Peak (dBFS)	Noise Floor (dBFS)	Signal/Noise Ratio (dB)
0.1449	-30.3	-61.2	30.9
0.4499	-22.3	-61.9	39.6
1.800	-17.5	-61.3	43.8
5.100	-17.4	-60.4	43.0
10.200	-16.7	-60.4	43.7
15.020	-14.6	-61.7	47.1
20.000	-15.1	-60.7	45.6
25.000	-17.3	-61.5	44.3
30.000	-15.3	-62.3	47.0
34.500	-27.1	-59.9	32.8
35.500	-31.8	-59.7	27.9
36.000	-34.6	-60.7	26.1

TABLE 2 NOTE: dBFS = dB relative to full scale

BANGGOOD SDR PERFORMANCE ON THE LF-HF RANGE (15.02MHz 30% AM signal)			
Signal Level (µV)	Carrier Peak (dBFS)	Noise Floor (dBFS)	Signal/Noise Ratio (dB)
22.4	-35.3	-61.3	26.0
12.6	-40.2	-61.4	21.2

TABLE 3 NOTE: dBFS = dB relative to full scale

have complementary ridges and slots) and then fitting a pair of M2 screws at each end.

Trying it out

I installed SDR# and its drivers (using Zadig, which comes with the SDR# package) on a couple of different Intel machines running Windows 7, 64-bit.

I did strike a bit of trouble initially because I had downloaded and installed the 64-bit version of SDR# and it didn't seem to be able to find the SDR device and its driver on either machine. Happily, this problem was solved by downloading and installing the 32-bit version.

Once I had SDR# up and running, I ran some tests on the 25MHz-1.7GHz tuning range, to verify the performance of the dongle. The results were quite promising.

For example, a 5µV NFM (narrowband FM) signal could be received clearly at various frequencies from 30.1MHz to 1.5GHz, with peak carrier amplitudes and SNR (signal to noise ratio) figures as shown in Table 1.

Then I ran some similar tests on the direct sampling 100kHz-30MHz tuning range, this time using a 224µV AM signal with 30% modulation. The results are shown in Table 2.

These are still quite respectable, although the sensitivity on this range is understandably rather lower than that on the 25MHz-1.7GHz range because of the lack of front-end gain. There were rather more spurious "birdies" too, because of the lack of any front-end tuning or preselection.

Note that I went beyond the nominal upper-frequency limit of 30MHz, just to see what the effect of the SDR's input low-pass filter might be. As you can see, the performance is still quite respectable up to 36MHz, so the filter doesn't seem to be too savage.

Since the performance with a signal level of 224µV was so promising, I decided to do a couple more tests at 15.02MHz (roughly in the centre of the tuning range), one with a signal level of 22.4µV, and the other with a signal level of 12.6µV. The results were still quite respectable, as shown in Table 3.

The bottom line

So here are the good points about Banggood's dongle-based SDR kit:

- its very low price
- quite respectable performance over most of the claimed tuning range, from about 100kHz to over 1.5GHz
- quality and completeness of the kit, right down to those extra SMD components and the additional M2 case assembly screws

On the other hand, here are the not-so-good points:

- there are some aspects of kit assembly that present quite a challenge, like winding the balun transformer T1 and then soldering the fine wires from its secondary to pins 4 and 5 of the dongle's RTL2832U chip
- the sensitivity and selectivity of the finished SDR does leave a bit to be desired, especially on the LF/HF direct sampling range. For serious listening, you'd be advised to use either a very long external antenna with a good earth and/or (preferably) an active antenna to provide both some gain and some preselection.

Actually, I can verify that the kit's performance does benefit from the use of an active indoor loop antenna because I tried it out with the low-cost SinoRadios TG34 antenna I reviewed back in the June 2013 issue of SILICON CHIP (pages 32-33).

It worked quite well, and when I looked on eBay to see if it was still available, I found it at: **www.ebay.com.au/itm/130392486862**

Banggood also had a very similar unit called the Degen DE31MS, which you'll find at: **siliconchip.com.au/l/aag5**

One final suggestion: although the extruded metal case of the Banggood kit does provide some shielding for the SDR circuitry, this could be improved by adding some short wires between the PCB earth copper and solder lugs attached firmly to the inside of the upper and lower parts of the case.

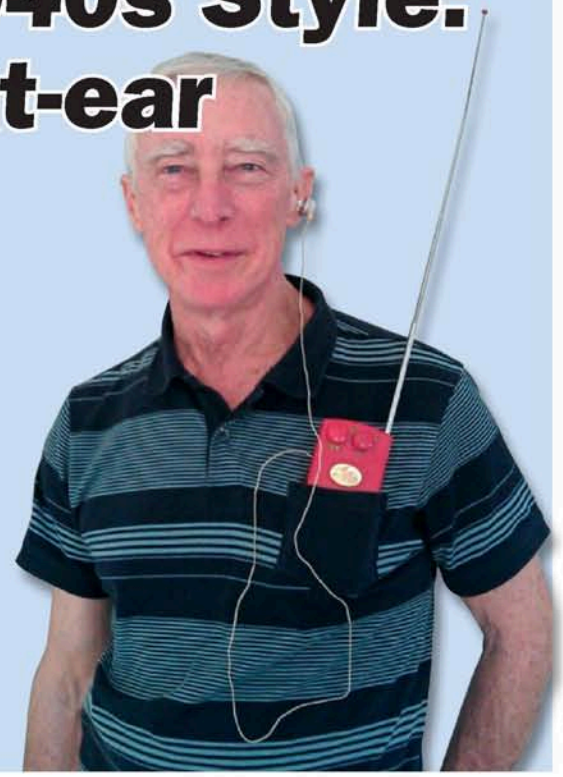
This ensures that the case is reliably connected to PCB earth, and so is able to provide full shielding, resulting in significantly lower interference. SC

Vintage Radio

By Ian Batty

Pocket Radio, 1940s Style: The 2-valve Privat-ear

This little portable radio looks like it might be an early transistor radio but it was produced in 1949, well before "trannys" became ubiquitous. In fact, it used subminiature valves and permeability tuning, which eventually became the standard in pushbutton car radios almost 20 years later. It was the ultimate in 1940s portability.



Valve technology experienced a technological revolution with the release of all-glass B7G miniature valves just prior to 1940. The initial release of a "superhet kit" of pentagrid, RF/IF pentode, diode-audio pentode and output pentode featured famously in Galvin's BC611/SCR536 "handie talkie" squad radio.

Civilian uptake was rapid, with 4-valve and 5-valve B7G portables dominating the postwar market and lasting almost up to the release of Regency's all-transistor TR-1 in 1954. Almost? Yes. There was a brief-and-brave interregnum fuelled by the development of subminiature battery valves.

To set the scene, consider an anti-aircraft shell. It has to go off near the enemy aircraft to have any effect, but how? You might try to set the fuse for a certain time, but you'd have to know how long the shell would take to approach the target. You might try an altitude setting but it's a bit hard to predict what the atmosphere might be doing at, say, 6000 metres altitude.

If only you could get the shell to go off near your target. A proximity fuse would do nicely. Put a small, expendable transmitter/receiver in the nose of the anti-aircraft shell, design it to go off when it detects a large metal object, and you would have an ideal solution.

Except that the radio has to survive an acceleration up to 20,000g (!) as the shell is fired. And so the subminiature valve was born. Building on the metallurgy and glass-making technology of the B7G, subminiature design eventually offered pentagrids, RF pentodes, diode-pentodes and output pentodes.

As well as a triode-hexode, a VHF triode that rivalled the "firecracker" 3B4 used in US-designed VHF backpacks, twin-triode equivalents of the 12AU7/12AX7,and even a subminiature version of the well-regarded 6AC7 video pentode.

Few all-subminiature valve sets were ever offered, as transistor technology took over in the late 1950s. And you'll find even fewer hybrid sets, using valve "front end" converter/IF/demodulator/audio designs and push-pull audio transistors in the output stage.

Frank Stuck's Privat-ear

Having developed subminiature valves during WWII, Raytheon acquired Belmont Radio to design and market subminiature valve equipped radios. The Belmont Boulevard, a complete, 5-valve superhet using the earphone cord as the antenna, was released in 1945.

Despite its outstanding design and miniaturisation, sales only reached some 5000 and the set was discontinued.

Frank L. Stuck, having previously registered US Patent 2521423 for a 3-valve radio, released the 2-valve Privat-ear through Electronics Systems Corporation in 1949. Obviously an economy design, it sold for as little as one-third the price of Belmont's Boulevard.

Being a 2-valve, non-superhet pocket radio and lacking a ferrite rod, you'd have to wonder whether the Privat-Ear could have worked at all. But ever the optimist, I got this little set off the shelf, fitted some batteries and gave it a try.

Few comparable sets exist. There's Belmont's Boulevard (mentioned above), the Pocket-Mite (a 3-valve kit released in 1948), and the 2-valve Tiny-Tooner. Other subminiature sets were released but these were scaled-down versions of conventional battery superhet portables.

You might mistake it for a hearing aid of the day but for its two controls and the striking red colour of the set I successfully tested. Other colours included maroon and white; distinctly different from the black cases commonly used for hearing aids.

First oddity: no power switch? Instead, you just pull out the telescopic antenna to turn it on; collapse it fully to turn off. It's not a superhet but a classic reflex design, albeit with a few wrinkles.

Consider that Regency's TR-1 (still a few years down the track) had to use a bulky air-spaced tuning gang but Frank Stuck decided to continue the use of permeability tuning as first described in his US2521423 patent.

Permeability tuning varies the inductance rather than the capacitance of the adjustable tuned circuits. It does this by moving the slug cores inside the inductors. Years later, most car radios would have permeability tuning to provide five preset stations with a preselect pushbutton mechanism.

What's unusual in this Privat-ear design is the two-"gang" design, with tuning slugs in both the grid and anode circuits. The mechanical arrangement is a bit agricultural but properly adjusted, it's effective and totally fit for purpose. It's also smaller than the 2-gang tuning capacitors of the day.

There are two versions of this tiny set, with both versions using just two subminiature pentodes in a reflex (regenerative) circuit. Fig.1 shows the first version, using 2E31s.

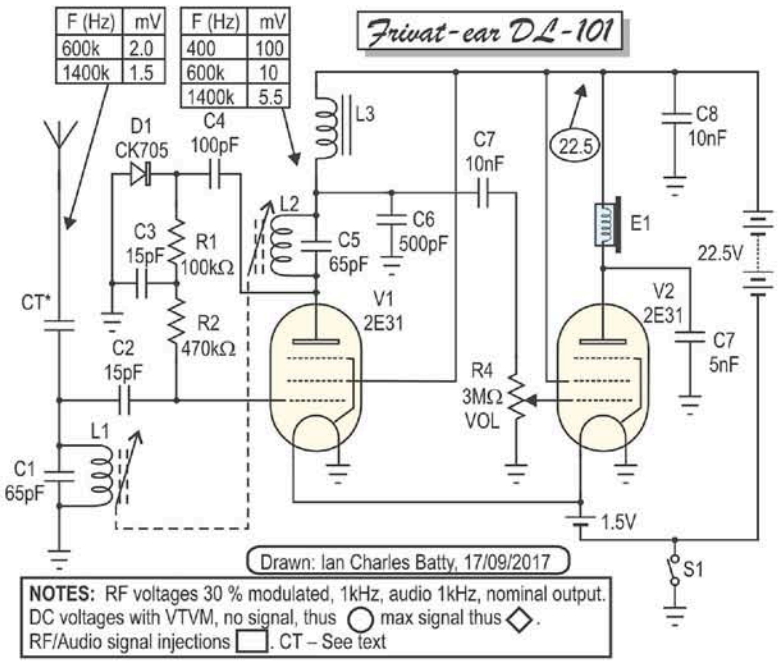


Fig.1: this unusual reflex radio used just two pentode valves which were subminiature types. Apart from being compact they also enabled the use of a very low HT voltage of only 22.5V. Another unusual feature of the Privat-ear was the use of permeability tuning which varied inductance rather than capacitance.

In essence, the first pentode is an RF amplifier which feeds a diode demodulator and that demodulated audio is fed back into the grid of the first valve into what is then a two-stage audio section. So in other words, it is a reflex design, as mentioned above.

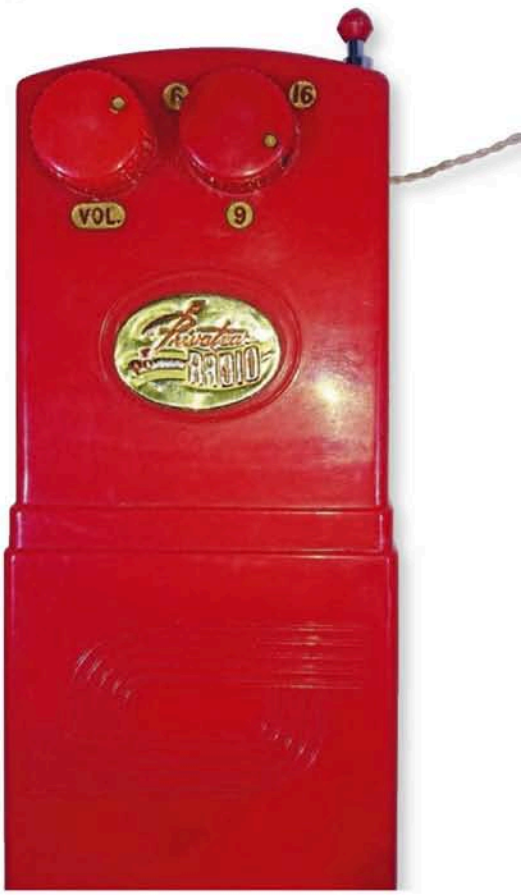
In more detail, both valves are described as pentodes but with the data sheet stating that "grid 3 is composed of two deflector plates, one connected to lead 3 and the other to lead 5".

The envelope is the T2X3 (2/8" x 3/8") favoured by Raytheon, with a flattened glass (ie, oval) cross-section and the connecting leads exit via the flattened section on the bottom. This was made by heating the glass to melting point and compressing the envelope to flatten and seal the leads; it's known as the "press".

I guess the assembly is so tiny that it made sense to omit a wound spiral construction for the suppressor grid and use the proven beam tetrode alternative.

This sees the screen winding accurately aligned to the control grid. This creates intense, flat beams of electrons whose density overcomes the lower-density nature of secondary electrons attempting to return from anode to screen. The "deflector plates" are added to condition electron flow on either side of the grid structure, where

Below: the Privat-ear uses two knobs, one for volume and the other for tuning. Tuning was not precise so the frequency indications are fairly vague.



"beaming" is less effective.

And the valve numbering? It's the Radio Manufacturers Association (RMA), a pre Radio, Electronics Television Manufacturers Association (RETMA) type. RMA number-letter-number codes were actively used for some two years from 1942 until they were superseded by the "5500" series which simply allocated sequential numbers. Reason took over with the RETMA coding beginning in 1953.

Under RMA's 1942 number-letter system, the first number is the heater/filament power: "1" for cold-cathode, "2" for power up to 10W and so on. The first letter designates the number of electrodes or type: B for a diode, C for a triode, D for a tetrode, E for a pentode and so on. The remaining numbers are allocated in registration order.

Thus a 1B23 is a cold-cathode radar Transmit/Receive tube (a diode) with a 20kW rating, the 2E31 is a subminiature pentode with a maximum anode dissipation of 45mW, and the 2J30 is a 300kW magnetron.

RETMA coded for heater/filament voltage and (more or less) number of electrodes but lost the indication of valve type. Thus the 1J6 was a 2V twin triode, while the 1H6 was a duo-diode triode, also with a 2V filament and the 1S5 was a 1.5V diode-pentode.

The set being reviewed here used the 6007 pentodes, as shown in Fig.2. As well as using a cylindrical T3 envelope rather than the 2E31 "flat" types, the 6007 gives about the same performance for only about 25% of the filament current; 13.5mA versus 50mA in the 2E31.

It's also a conventional pentode with a wound suppressor grid. One of my sets used a handmade spiral of wire to shield V1 to prevent regeneration and oscillation; unnecessary with the spray-shielded 2E31.

The Privat-ear is assembled into a plastic chassis, a bit like the previously-reviewed Deutscher Kleinempfänger DKE38 set featured in the July 2017 issue (siliconchip.com.au/Article/10728).

I found the Privat-ear difficult to work on. The valve leads were protected by plastic sleeving to prevent shorts and many component connections onto the plastic chassis were buried under the actual components.

In detail, the telescopic antenna rod connects directly to the RF amplifier's grid tuned circuit comprising capacitor C1 and variable inductor L1. The direct connection doesn't attempt to compensate for the electrically "short" antenna or its considerable capacity. Since the antenna connects directly to C1/L1, I would have expected the wearer's body capacitance to have some effect on grid tuning. We'll find out later on.

C1 is only 65pF and about one-fifth the value you'd find in a capacitance-tuned circuit at the 535kHz end of the broadcast band. This also implies a high inductance value for L1, and if L1

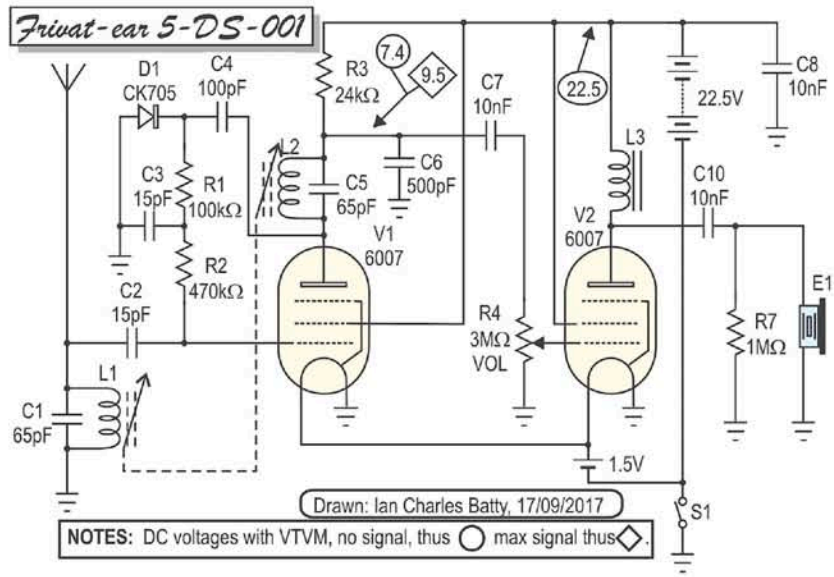
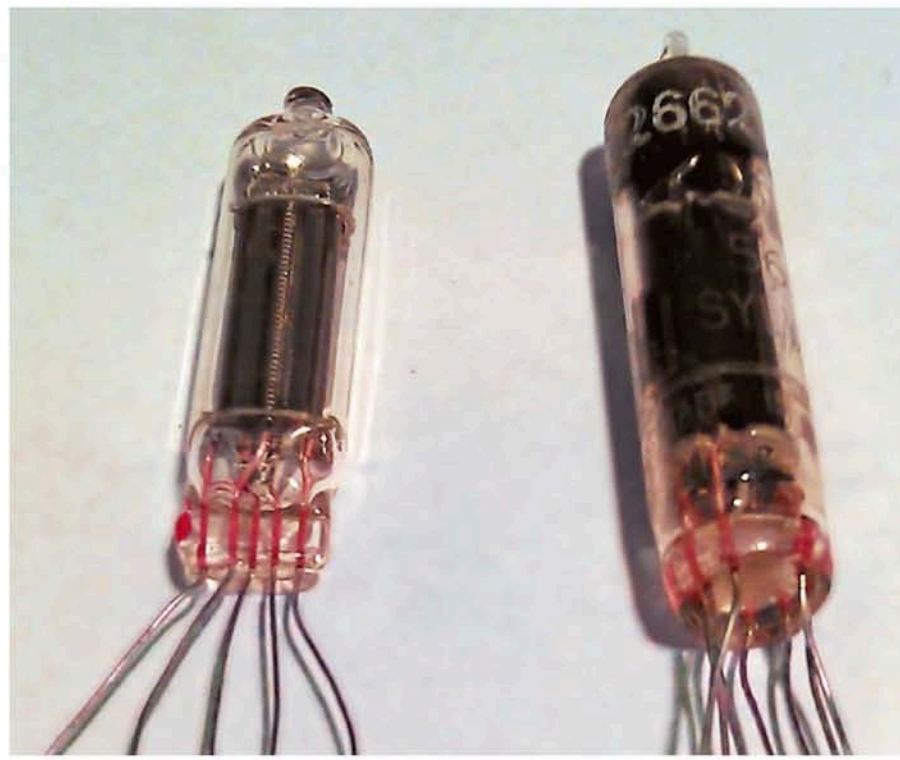


Fig.2: the second version of the Privat-ear circuit diagram used 6007 valves. The other major difference in this version is that the earphone is piezoelectric and is coupled to the pentode plate via a capacitor.



This photo shows the construction of the two subminiature valves employed in the two versions of the Privat-ear. At left is a T2X3 6088 hearing-aid output pentode, with its connecting leads exiting the envelope via the flattened section on the bottom. At right is a subminiature version of the landmark 6AC7, with a cylindrical T3 envelope.

is a low-resistance coil, this implies a very high Q (selectivity factor) for both tuned circuits. Since it lacks a high-selectivity IF stage, the Privat-ear will need all the Q it can get from its two tuned circuits so that it can separate stations adequately.

The signal from the tuned antenna circuit connects to RF amplifier V1 via a 15pF coupling capacitor, C2. Having just finished a series on transistor sets, I'm reminded of the very much higher input impedances of valves and the much lower values of coupling capacitors they can utilise.

RF amplifier V1 gets its grid bias, via resistors R1 & R2, from demodulator diode D1. I'd expected to see the diode's anode as the active connection, as this would give a negative-going output signal and would supply conventional AGC (more negative bias with stronger signals). But in this set, it's just the opposite.

According to the diagram, D1 (since it will conduct on negative-going peaks) will produce a positive-going signal, with V1's grid going less negative/more positive on stronger signals; more on this the point later.

V1 develops an amplified version of its grid signal across the anode tuned circuit comprising capacitor C5 and variable inductor L2 (ganged with C1/L1). This amplified signal is fed to demodulator diode D1 via 100pF capacitor C4. The diode rectifies the applied signal to produce a positive DC voltage proportional to signal strength, and would appear to also produce a positive-going DC voltage.

D1, being a point-contact germanium diode, will need some 100-150 millivolts before it conducts, which means it would need a lot of signal. But D1's cathode connects via R1-R2 to V1's grid and V1 will produce a weakly negative grid voltage due to its "Edison effect".

In practice, D1 gets some forward bias, helping it to conduct with signals well below its normal forward voltage. So this circuit is very similar in principle to transistor radio demodulators, where the diode is also given weak forward bias.

Privat-ear interior details

The internal view confirms the set's simplicity. The two tuning coils appear at top left (anode circuit) and lower right (antenna), with the telescopic antenna just beneath the lower coil. The RF/1st audio valve appears just above the antenna coil and the audio output valve is above the RF/1st audio and slightly behind it.

The dark maroon disc on the left is the top of the tuning capstan, and the black tuning cord runs from the capstan to each tuning slug on their left-hand ends. Another cord joining their right-hand ends and passes over a tensioning spring about half-way up the battery cover on the right.

The CK705 demodulator diode (looking like a ceramic fuse) sits just above the tuning capstan, with the audio choke used as the anode load for the second pentode, V2, being at the top right of the component section.

This choke is in the same place for both models. Other components are scattered about in the compartment, comprising flat disc and tubular ceramic capacitors and common quarter-watt resistors.

The volume control sits above the tuning dial capstan, with its two securing nuts just visible. The battery compartment carries two AA cells connected in parallel for the filament supply and a type 412 22.5V HT battery. The copper strip of the on/off switch lies beneath the 22.5V HT battery.

Cleanup

Both of my sets showed cracking in the battery compartments but surprisingly there was no battery corrosion. A spot of superglue on each repaired the cracks, and a clean and polish brought them both up nicely.

The maroon set was dead, and testing showed the audio choke on the output valve to be open circuit. It's the type commonly used in hearing aids, but I'm reluctant to wreck any in

The Privat-ear utilised a quite large telescopic antenna (as seen fully extended in the lead photo), especially compared to other subminiature valve radio sets that were being produced in that period. To switch the set on, the antenna needed to be extended to operate the on/off switch lever located next to the 22.5V B battery.

my collection, so I'll just leave that set and look out for a replacement choke.

How good is it?

Its performance was better than I expected. While its selectivity can't match that of a superheterodyne radio, it pulls in eight local Melbourne stations just fine down here on the peninsula.

Injecting a signal for testing presented some difficulty. Lacking a ferrite rod antenna, I couldn't rely on my usual method of inductive coupling from the radiating ferrite antenna that I've used successfully for many previous sets.

So I used the method previously tried on Sony's TR-63 when I was unable to inject a signal directly onto its converter base. Here, I used a 4.7pF capacitor (labelled CT on Fig.1) and jiggled the antenna circuit's slug for maximum gain.

While I can't guarantee my signal voltage to translate directly to a V/m figure, the method does allow anyone else to reproduce my results and judge whether their set is working correctly.

Measuring the audio output level presented another problem. I couldn't find any standard that I could apply, so I set up my signal generator with program audio modulation and just went for "a good listening level".

Sensitivity? Using my series 4.7pF capacitor into the antenna, it was around 1.5mV at 600kHz and 1400kHz. More objectively, –3dB selectivity is ±4kHz and ±20kHz at 600kHz and 1400kHz, respectively. These figures imply combined-circuit Q factors of 75 and 35 respectively.

Importantly, bandwidths are around ±70 and ±170kHz at –20 dB. The broad selectivity was borne out in use, with strong stations flooding the space between them and obvious instances of the 9kHz "whistle" caused by adjacent stations. I'd wondered whether hand/body capacitance would affect the antenna circuit tuning, and found that it does, to some extent.

As expected, the demodulator's DC output was positive-going, overcoming V1's Edison effect bias of around -130mV and sending the grid positive. The test set, with low DC resistance from anode to supply, showed no significant voltage change with signal strength.

The other set (using resistance-capacitance coupling) did show a change in anode voltage from 7.5V to 9.5V on strong signal, despite its grid voltage going slightly positive. That's opposite to what I'd expected and if a reader can offer an explanation I'd be happy to know of it. On test, I could not identify any AGC effect.

Its audio performance was adequate for the purpose. With such close coupling into the ear canal, "some tens" of microwatts translates into a good listening level.

So would I buy another one? I've already done so. You may like to add one of these unusual sets to your collection. It's more on the "enthusiastic amateur" side than the "engineer employed by mega-corporation" side of electronics, but I think that's a large part of its charm.

Two Privat-ear versions

Besides the different valve types used in the original DL-101 (2E31) and the later 5-DS-001 (6007s), there are some other subtle circuit differences.

Anode current for the first audio stage (V1) in the DL-101 flows from the battery through choke L3. This gives maximum gain with a much lower voltage drop than a load resistor.

The output stage (V2) drives the magnetic earphone (E1) directly, ie, it's between the anode of V2 and the B battery. This earphone has a DC resistance of only a few kilohms, so there's little voltage across it.

By contrast, the 5-DS-001 uses a crystal (piezo-electric) earphone, which has a high DC resistance so this can not be connected in the same manner.

So the first audio stage load is resistor R3, giving a lower V2 anode voltage in this set. Choke L3 is the DC load for V2 with C10 providing DC blocking, to prevent V2's anode voltage appearing across earphone E1. R7 shunts any leakage via C10 to ground.

Note that the move to 6007s improved battery life considerably due to their lower filament current. Allowing for carbon-zinc AA cells of the day with capacity of some 500mAh, the two paralleled cells used would run a pair of 6007s for around 40 hours.

While it's not the hundred-plus hours of later transistor sets, this is about double the battery life of the first transistor radio, Regency's TR-1. HT battery drain is similar across all models and, I'm guessing, well over 80 hours of B battery life.

Both my sets suffered a broken corner just below the B battery. It seems that the plastic case had become brittle with age, so gentle handling is recommended. As well, one had suffered a stress break in the opposite corner caused by excessive spring tension in the A battery positive connection leaf – I'd recommend easing the tension off.

The Privat-ear's "throw stuff down and solder it in" construction makes it a challenge to work on. If you do intend to fix a Privat-ear, apply lots of care and patience with your existing skills.

Further reading

For a very fine and detailed description, with history and photos, see: www.jamesbutters.com/privatear.htm

For an exceptional catalog of American valves of all kinds, refer to: *Tube Lore by Ludwell Sibley, ISBN 0-9654583-0-5, 1996, Chernay Printing, Flemington, NJ.* SC

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Transmitting TV to another room

Is there any wireless way to transmit a TV signal from one room to another if no aerial socket is available in the other room? I'd imagine an RF signal does not lend itself to be "carried" to another room.

I have seen AV and HDMI transmitters which seem to be the only other option. Have you had much experience with these? (G. B., via email)

● The RF signal from the room that has the RF antenna socket could be split (using a TV antenna splitter) with one output for the TV in that room. The second output can then be connected to a masthead amplifier suitable for digital TV transmissions and small basic wire antenna used to transmit to the other room.

The other room can use a similar basic wire antenna (or rabbit ears) to receive the RF signal for the second TV. The possible range using this method will depend on the wall type between rooms.

We published an article in the December 1991 issue titled "TV Transmitter For UHF VCRs" that may be of interest; it was designed specifically to do this job. You can order a photocopy of this article at siliconchip.com.au/Shop/2/115 or a PDF scan at siliconchip.com.au/Shop/5/2904

Alternatively, you could use a set-top box in the room with the antenna socket and then transmit its video output to the TV in the other room using transmitter/receiver units such as Jaycar AR1913 (analog) or AR1915 (HDMI). These both include IR remote control extenders so that you can change channel from the remote room.

Building a DIY mains isolation transformer

I have found myself with a requirement for a 240V mains isolation transformer but the commercially available units are too expensive for me.

I have several identical toroidal transformers and I am wondering if two of them can be used in a back-to-back configuration. The transformers have an untapped primary winding for 240VAC and two secondaries of 12V each. They are rated at 200VA.

I assume that the two secondary windings would be connected in series and the pairs of secondaries would then be connected together, giving both an input and an output of 240VAC.

Can you please advise if this would be a suitable arrangement? Other than the obvious precautions to be observed when working with mains voltages, can you see any problems with this approach? (B. D., Hope Valley, SA)

● Have look at the Salvage It article on page 82 of the May 2014 issue (siliconchip.com.au/Article/7649). This is about making an isolation transformer with two standard power transformers. However, one point which must be made is that the output must not be earthed and this was the subject of correspondence in the Mailbag pages of the subsequent July 2014 issue.

Solar panel wiring polarity

The circuit diagram (Fig.1) for the Arduino Data Logger on page 28 of the August 2017 issue (siliconchip.com.au/Article/10749) shows the solar panel wired + to Mini Solar LiPO Charger + and same for the – terminals of both devices.

However, the photo of the actual devices on page 29 shows a black (negative?) wire from the solar panel connecting to a red (positive?) connection to the LiPO charger (and vice versa).

So is it + to + as per the circuit diagram or – to +? (C. K., Oxley, Qld)

● Follow the circuit diagram and connect + to + and - to -. Despite the connectors being polarised, there's no standard for wire colours on JST cables. So sometimes you get wires which when plugged in give red for + and black for - and sometimes you get black for + and red for -. The wires we used were the latter type.

In fact, if you look closely at the photo on page 29, you can see that the terminal labelled + on the battery goes to the black wire which then connects to the terminal labelled + on the Solar Charger PCB.

Similarly, you can see that the red and black wires which are soldered to the solar panel connect to the black and red wires respectively on the JST cable, which then go to the + and – terminals on the Solar Charger board.

It's a pity that the wire colour codes don't match the PCB; we are trying to source suitable cables (which we know exist) but vendors rarely provide enough information to determine in advance which polarity they will be supplied with.

Induction Motor Speed with a 0-3.3V signal

I want to build the Altronics kit for the 1.5kW Induction Motor Speed Controller (Cat K6032), based on your articles in the April and May 2012 issues (siliconchip.com.au/Series/25). I see that it uses a 0-3.3V signal for speed control.

Can this signal be fed in from an external board or is this voltage adjusted using a potentiometer on the PCB? Can you send me a datasheet/documentation for this product? (I. M., Gauteng, South Africa)

● The 3.3V signal could be fed in from an external board if you wished, provided its ground reference is tied to the GND terminal of the connector CON4. A list of Features and Specifications is provided on page 17 of the April 2012 issue. You can view this on our website at: siliconchip.com.au/Article/704

Adapting DDS software to run on Plus Backpack

I purchased the Micromite Plus Backpack kit by accident. I had intended to purchase the standard Micromite

Backpack kit to make the DDS Signal Generator project as described in the April 2017 issue (siliconchip.com.au/Article/10616).

I have found the Micromite Plus Backpack has a different pin-out and the DDS software "almost works" on it. Is there somewhere in the BASIC code that can be modified to change the pin assignments to suit the Plus Backpack?

Pins 16, 17 & 18 on the standard Micromite are easily re-assigned to other pins on the Micromite Plus. The problem pins are 3 and 25, as they do not appear to be specifically mentioned in the code. (W. S., Lake Cathie, NSW)

● We tried to make the Plus BackPack as compatible as possible with the original BackPack but the pin capabilities of the chips are different, so it couldn't be made 100% compatible.

Part of the difficulty was that we had to choose between keeping the Micromite pin numbers on the I/O header the same or keeping the functions the same but not both. We decided on the latter since pin number assignments are not normally difficult to change.

You are right that the references to pins 16, 17 and 18 are easily changed in the code, near the top of the file. These should be changed to 51, 44 and 43 respectively. The other two pins, 3 and 25, are SPI OUT and SPI CLK on the original Backpack. On the Micromite Plus LCD Backpack, these same pins on the I/O header are connected to pin 8 (SPI1 OUT) and pin 50 (SPI1 CLK).

The SPI command in MMBasic uses the SPI1 channel by default so you shouldn't need to change those pin allocations at all. But there is one other thing you need to do, besides changing the three pin assignments.

Because the original Micromite lacked a touch interrupt function, Geoff has used the following "hack" to provide this feature:

```
SetPin Peek(byte Peek(word
  &H9D000090) + 23), INTL, MyInt
```

The problem is that the Peek() function reads a specific location in RAM to determine the pin which is used for the touch interrupt function. This location will be different for the Plus Backpack so this line (which appears twice in the code) will fail. The solution is to use the proper touch interrupt function that was introduced with the Micromite Plus. Change both lines to read:

```
GUI INTERRUPT MyInt
```

The software should then run OK on the Plus Backpack.

Increasing EEPROM programming voltage

In the last year, I have finished building the EPROM Programmer from the November and December 2002 and January 2003 issues (siliconchip.com.au/Series/110). I have been able to read 2716 EPROM chips OK using the adaptor.

Now I would like to program a 2716 chip as I have a Tait UHF Transceiver that uses the 2716 for its channel frequencies. My question is whether the power supply of the programmer will be able to handle this, as the 2716 requires 25V for V_{PP} (programming voltage). I don't want to burn out the programmer after all the work building it. (K. M., Grovetown, NZ)

● You should be able to increase V_{PP} in this project to 25V without any problems. All you need to do is change the 3.9kΩ resistor from the ADJ terminal of REG3 to ground to 4.7kΩ and remove the parallel 150kΩ resistor.

The 12VAC power supply should provide enough voltage to REG3 to allow its output to be increased in this manner. That should give you a V_{PP} of about 25.5V. We suggest checking this before plugging in the chip to be programmed. All the other components can handle a V_{PP} of 25V.

Two SC480 modules with a valve preamp

I emailed you a few years ago and you published my letter regarding home-made phase changers; I'm writing today as I purchased two SC480 amplifier kits at a market.

I've started constructing them but I'm wondering if I were to use a stereo valve preamp (www.ebay.com.au/itm/192176319933), would this allow me to use it as a regular amplifier with volume control from sources such as TV, CD, turntable, etc? (D. E., via email)

● Yes, it will do what you want but we doubt whether that preamp would match the performance of the SC480 modules. If you really want to use a valve preamplifier, why not use our own Stereo Valve Preamplifier design, described in the January & February 2016 issues.

You can view previews of the arti-

Using USB-serial bridge with November 2009 GPS Analog Clock

I built the GPS Synchronised Clock for Sweep Hands, as published in the November 2009 issue (www.siliconchip.com.au/Article/1632) but I never got it going properly.

The updated version in the February 2017 issue (www.siliconchip.com.au/Article/10527) rekindled my interest so I got it out and had another go.

I got a new clock motor and modified it. The clock starts but skips a second here and there so I want to lengthen the pulse. I connected to a USB-serial bridge and used the cable connections from Geoff Graham's website to make sure they were correct. But all I get is garbage.

I have been using a Micromite for many years so am familiar with using TeraTerm. I tried another PIC chip and have tried the software from both the SILICON CHIP website and Geoff's site.

The serial bridge is OK as it echoes back characters when TX and RX are shorted. Do you have any suggestions? (P. C., Balgal Beach, Qld)

● The 2009 design is not directly compatible with a USB/serial inverter since it used RS-232 signalling (ie, inverted compared to TTL serial).

We had to modify the software for the February 2017 version to produce TTL-compatible signals, so that we could interface it directly with a USB/serial adaptor.

You either need to fit something like a MAX232 between the USB/serial adaptor and the PCB, to invert the signals, or use a USB/serial adaptor with RS-232 compatible outputs, such as a PICAXE programming cable.

Or simply add inverters between the two devices.

cles via this link: siliconchip.com.au/Series/295

We have a range of hard-to-get parts for this project on our website, including the acrylic case and PCB. Or for even lower noise and distortion, you could consider building our Ultra-LD Stereo Preamplifier and Input Switcher and mounting it in a small instrument case; see siliconchip.com.au/Series/34

40V battery pack with 2014 Voltage Switch

I recently visited our local Jaycar outlet to purchase a voltage switching circuit. Your Threshold Voltage Switch design from the July 2014 issue, kit code KC5528 was suggested (siliconchip.com.au/Article/7924) but some alterations would have to be made. I wish to switch a relay to turn a charging circuit off when terminal voltage of a battery reaches 40V DC. The charger that I am using produces 45V 3A. Is this possible and how can it be done?

The reason for this that I am using battery packs from a hybrid vehicle to power a 36V eBike that I have built. It works well except batteries don't handle being overcharged well. I hope you can help. (G. L., Dunedin, NZ)

- You will need to provide a suitable supply voltage to run the Threshold Voltage Switch, in the range of 5-24V. You should be able to adjust the Threshold Voltage Switch to switch at a threshold of 40V.

Just set VR3 fully clockwise (the threshold adjustment) to the maximum, 3.3V. Then with LK1 inserted to divide the monitored voltage, adjust VR1 (the divider) so that at 40V, the relay is switched.

Automotive Sensor Modifier voltage range

I purchased the December 2016 issue as I am interested in the function of the Sensor Modifier (siliconchip.com.au/Article/10451). The problem is I actually need a 4.5-9V input signal to calibrate a fuel tank setup after installation of a larger auxiliary long range tank, rather than a 0-5V signal.

I understand the December 2009/January 2010 Voltage Interceptor design (siliconchip.com.au/Series/6) had a 0-12V mode which with 255 load points would work fine for my application (extreme accuracy not essential). Can the Sensor Modifier be altered to work in a similar manner? Is it just a case of resistor changes to change the reference voltage? You will have to forgive me as I am not an electronics expert. (A. C., West Lakes, SA)

- You could connect the fuel level sensor to a 5V supply so that it produces a voltage in the range of 0-5V instead. That would give a more accurate result as its output would not vary with the vehicle's 12V supply that can vary over a wide range from below 12V up to at least 14.4V.

If that is not suitable, you could alter the Sensor Modifier to work with an input and output range of 0-10V, as follows. First, solder a 100kΩ resistor from pin 12 of IC1 to ground (pin 11). This will reduce an input of 0-10V to a range of 0-5V, to suit IC2.

Next, cut the supply track to pin 4 of IC1 and wire pin 4 up to the cathode of ZD1 instead, so that the op amps run off a higher supply voltage. Note that you will need to cut both tracks to this pin (top and bottom layer) and run a second wire to replace the connection which is lost when you do this.

You will then need to replace the 1kΩ resistor between VR1 and GND with a 2.2kΩ resistor and solder a 56kΩ

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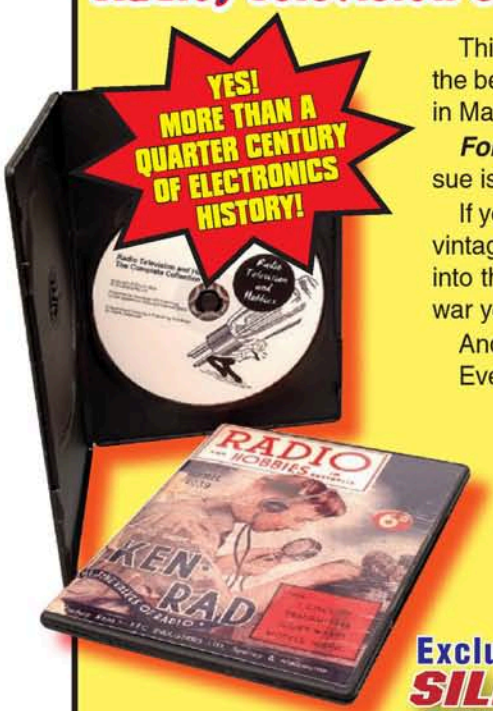

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resistor between pins 2 and 7 of IC1, in parallel with the existing 100kΩ resistor. These changes will allow the unit to alter the output voltage over the full range 0-10V.

VS1053 module appears to have dodgy soldering

Hello, I recently purchased a Geeetech VS1053B MP3/audio shield for Arduino from your online shop. Before using it, I noticed two solder bridges on the VS1053 IC. Please see the photo below. Can you send me a replacement board? (R. McE., Ringwood North, Vic)

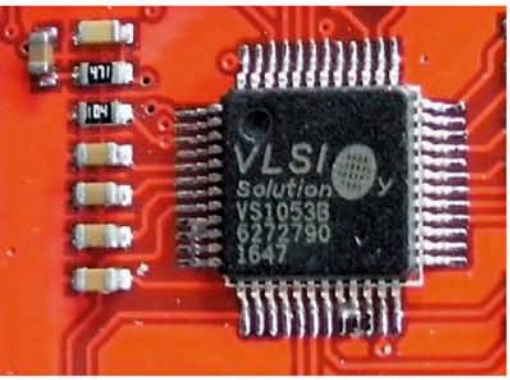
● While the soldering on some of these modules may look dodgy, they should all work OK. In fact, if you have a look at the module in the photo on page 76 of the July issue, you will note that it has some of the pins bridged in the same way as in your photo.

Pins 20, 21 and 22 on this IC all connect to ground and they have done this by simply running a track between the three pads. This is not a practice we recommend since with pads this close together, this tends to cause solder bridges to form (we prefer to run tracks out from the ends of the pads and then join them away from the pads).

Of course, solder bridges between pads which are intentionally joined will not cause any problems but they do make it harder to inspect the IC for accidental bridges.

Since you've pointed it out, we also noticed that unused pins 9, 10, 11 and 12 are all joined together on the PCB and so we would expect some boards to have these bridged too. We showed them not connected to anything in our circuit diagram on pages 74 and 75 of the July issue since those pins don't go anywhere, but for some reason they have decided to join them together.

We would expect that all of these modules have been subjected to a normal "bed of nails" QC test and so any accidental shorts should have been picked up. Power it up and see how you go. If your module is indeed faulty, let us know and we will send a replacement.



Small design flaw in Battery Lifesaver

Regarding the Lifesaver for Lithium/SLA Batteries published in SILICON CHIP in September 2013 (siliconchip.com.au/Article/4360), I note that there is a design error with the connection of the common cathode of the D1/D2 (BAT54C) and the non-inverting input to comparator IC1 (pin 3).

Surely if the A1 diode in D1/D2 was to clamp pin 3 of IC1 to about 5.2V, the cathode (K) must be connected to the 5V output of the linear regulator and not the input (which can go as high as 16V).

It would seem that there need to be two separate diodes, ie one for reverse polarity protection to the linear regulator and one from the non-inverting input (pin 3 of IC1) to the 5V rail.

The way the circuit is presented in Fig 2 of the article, I can't see how D1/D2 will clamp the input to the comparator – potentially destroying the comparator input, although the resistor dividers limit the current significantly. (K. N., Kingston, Tas)

● You are right that there was a mistake with the diode clamp in that design. We discussed this in the Ask SILICON CHIP pages of the January 2014 issue (pages 102-104). The comment there was: "As for the diode clamp, you are right [that it was a mistake] but luckily it isn't critical. The divider resistors limit any current that might flow into the comparator's input clamp diode to a safe level."

Therefore, we agree with your assessment. We haven't heard of any problems resulting from this error. You're right that leakage current through the reverse-biased diode junction will cause a shift in the threshold voltage. This can be adjusted out using VR1, however, it will cause the threshold to change slightly with temperature.

If you're concerned about that, you could just use a regular BAT54 in its place (which lacks the redundant diode) or else cut the track between pin 2 of D1/D2 and trimpot VR1, on the top side of the PCB.

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Ask Silicon Chip: issues with the Arduino Data Logger

I have built the Arduino Data Logger described in the August and September issues (siliconchip.com.au/Series/316). I used your custom PCB and it all works well, including the GPS unit. I did have to overcome a few minor hurdles to get it working, though.

Firstly, I noticed in your photos that the wires from the GPS module were wired to the socket on the PCB in the same order as they emerge from the GPS unit.

Instead I found that I had to swap the TX and RX lines (green and blue) on my logger to get it to work. I also couldn't get the serial console to work at first, until I realised that I had to change the baud rate to 115,200 in the Arduino IDE.

I also had problems getting a DS18B20 temperature sensor to work at first. I wired it up to Arduino pin D2, as shown in Fig.1 on page 28 of the August issue but I got an error message from the software that the sensor wasn't found.

I had to change the line in the code which read "OneWire ds(DS18B20_INPUT+2);" to "OneWire ds(DS18B20_INPUT);" and then it worked, although the temperature readings showed up in the wrong location in the log file (in place of the third digital input, rather than the first).

I also connected a GY-68 Barometric Pressure Sensor to my Data Logger and used the supplied example sketch. It all appears to work correctly and the temperature reading is correct.

But the pressure reads in bar, for example, "1.002" which is not particularly accurate. Is it possible to change the sketch so that it outputs the pressure in millibars or hectopascals to the log file?

This would give a reading like 1024.5 which is more like what is available from weather stations or off the web. If possible, the sketch could be updated for download. Thanks for a fine magazine. (C. W., Leumeah, NSW)

● Thanks for your feedback. Chances are, other readers will run into similar issues.

It looks like we accidentally connected the GPS TX pin to the micro's serial TX pin and RX to RX on our PCB for this project, rather than TX to RX and RX to TX like we did on our initial protoboard version.

Swapping the order of those wires in the header plug is the simplest solution.

We probably should have mentioned that you need to set the Arduino serial monitor baud rate to 115,200.

This was used as it's the highest baud rate which is commonly supported and it minimises the amount of time the Arduino spends transmitting data to the PC. We forgot that the default for the IDE was 9600.

You can usually determine the baud rate required for a given sketch by looking in the setup() routine for the call to Serial.begin().

We realise now that naming the four digital inputs for the Data Logger D0-D3 means they can easily be confused with the Arduino's digital pins D0-D3.

As explained in the article, we had to use inputs D2-D5 because D0 and D1 are reserved for use by the main USB serial port.

While we show the DS18B20 connected to digital input #0 (Arduino pin D2) in Fig.1, we actually had it connected to digital input #2 (Arduino pin D4) on our prototype for testing, hence, the sample sketch contains the line:

```
//#define DS18B20_INPUT  2
```

If you're using the DS18B20 as shown in Fig.1, you should change this to:

```
#define DS18B20_INPUT    0
```

We suggest you do this and change the OneWire definition back to its original version. You will then find the DS18B20 temperature will be in the correct place in the log file. Sorry about that. Our sample sketch should have probably set up the DS18B20 input as #0 from the start, to match Fig.1.

Regarding the pressure reading, only a few lines of the code need to be changed to give a pressure reading in hectopascals with one or two decimal places.

Note that while the BMP180 sensor gives readings with a resolution of around one pascal, the absolute accuracy is only around one hectopascal (depending on temperature, altitude, etc); see the data sheet for more details.

The first line to change reads:

```
// in bar
BMP180buf[log_ram_filled][1] =
   bmp085GetPressure(
   bmp085ReadUP()) / 101325.0;
```

change this to:

```
// in pascals
BMP180buf[log_ram_filled][1] =
   bmp085GetPressure(
   bmp085ReadUP());
```

This stores the pressure in pascals rather than bar. Next, we change the very end of the log format line which reads:

```
static const char
   LogEntryTemplate[]
   PROGMEM = "%02d/%02d/
   %04d,%02d:%02d:%02d,%d.
   %02d,%d.%02d,%d.%02d,%d.
   %02d,%d,%d,%d,%d,%d.
   %01d,%d.%03d";
```

to this:

```
static const char
   LogEntryTemplate[]
   PROGMEM = "%02d/%02d/
   %04d,%02d:%02d:%02d,%d.
   %02d,%d.%02d,%d.%02d,%d.
   %02d,%d,%d,%d,%d,%d.
   %01d,%d.%02d";
```

This sets the number of decimal places for the pressure reading to two.

Then where it writes the pressure into the log, we change these two lines:

```
,(int)BMP180buf
   [log_ram_filled - 1][1]
,(int)((int)(BMP180buf
   [log_ram_filled - 1][1] * 1000))
   % 1000
```

to this:

```
,(int)(BMP180buf
   [log_ram_filled-1][1] / 100)
,(int)((long)BMP180buf
   [log_ram_filled-1][1] % 100)
```

This converts the value in pascals to hectopascals by dividing by 100 for the integer portion and computes the modulus 100 for the two decimal places.

We've tested this program and it works well. This new example script will be available for download from our website. SC

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Next Month in Silicon Chip

Electromagnetic Launchers and Rail Guns
Dr David Maddison takes a look at these devices which are starting to take over launch duties on aircraft carriers and may eventually replace the guns on navy ships. They offer significant advantages for aircraft launching compared to steam catapults and as weapons, offer the possibility of a potent weapon with a much smaller weight and size compared to a traditional gun.

Super-7 AM Radio part two
We'll present the PCB design for the Super-7 AM radio and go through the assembly, testing and set-up/alignment procedure for this radio. We will also show you how to assemble the custom-made Acrylic case.

nRF24L01+ 2.4GHz Wireless Data Transceiver Modules
Jim Rowe describes the operation of these 2Mbps digital radio modules with software that lets you communicate with a pair of Arduino or Micromite modules. This article was held over from last month due to space constraints.

WiFi Water Tank Level Meter and Weather Station
This project uses a commercially available pressure sensor and ESP8266 controller board to upload water tank level, temperature, humidity and barometric pressure periodically to "the cloud". You can check the data and plot it in graphs from a smart phone, tablet or PC from just about anywhere. It's solar powered and easy to build and set up.

Temperature-based Proportional Fan Controller
This design is simple and compact yet very useful. It can control a small or large fan to cool a computer, automobile or even house - whatever you need to force air through. It switches the fan on and adjusts its speed depending on a temperature reading and also includes a low-battery switch-off feature with extremely low quiescent current.

Note: these features are prepared or are in preparation for publication and barring unforeseen circumstances, will be in the next issue.

The December 2017 issue is due on sale in newsagents by Thursday, November 23rd. Expect postal delivery of subscription copies in Australia between November 23rd and December 15th.

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Notes & Errata

GPS-Synchronised Analog Clock Driver, February 2017: another bug has been identified in the sweep hands version of the software. Its output drive waveforms were not always correct and this caused weak output drive and potentially slow operation. A new version of the firmware, v1.4, is now available for download from the Silicon Chip website which solves this.

Deluxe Touchscreen eFuse (July, August & October 2017): a couple of changes need to be made to prevent false tripping and rebooting. First, change the two 4.7kΩ resistors to 100kΩ. Then, add two 220pF capacitors. The first one goes between the base (middle pin) of Q2 and the nearby ground point, where the adjacent 30kΩ resistor connects to the large ground trace. This can be mounted on the underside of the PCB. The second 220pF capacitor is similarly connected between the base of Q4 and ground; the top end of the nearby 100nF bypass capacitor for REG3 can be used (it's connected to the middle pin of REG3 by a track on the top side).

Li-ion and LiPo Charger Modules, August 2017: on page 44, the article refers to red LED2 and green LED1. It should instead refer to red LED1 and green LED2, to be consistent with the circuit diagram (Fig.1) on the following page.

3-Way Active Stereo Crossover for Loudspeakers, August-September 2017: 38 1kΩ SMD resistors are required, not 37 as stated in the parts list on page 34 of the September issue.

0.01Hz - 6GHz+ Touchscreen Frequency Meter, Part 1, October 2017: on pages 28 & 29 timer 2/3 and timer 4/5 should be swapped with regards to their explanation. The block and circuit diagram are both correct.

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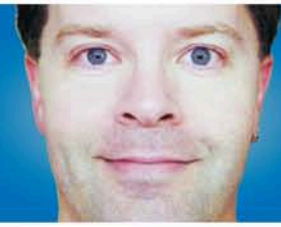

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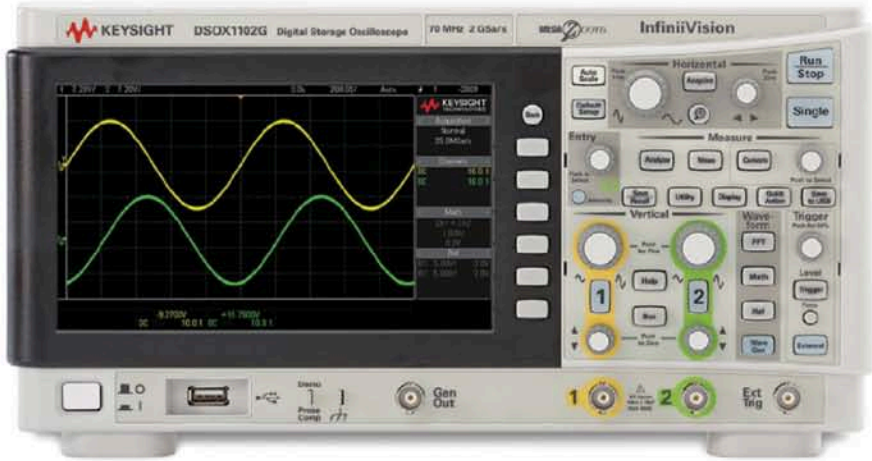

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